AN ECONOMETRIC STUDY OF PRODUCTION EFFICIENCY AMONG RICE FARMERS IN IRRIGATED LOWLAND VILLAGES IN JAVA, INDONESIA

Sri Widodo*)

Abstract

The study of farm production efficiency has been not only a popular field of research in the field of agricultural economics, but also an important part of the development policy due to the strategic position of agriculture in many developing countries. Most of the studies of production efficiency have been in price or allocative efficiency, mostly by using production function approach, recently by using profit function approach and some by using householdutility function approach, those are inspired by the Schultz's efficient farmers. Some others dealt with technical efficiency or management component of the factors of production by including such dummies or indeces as proxies. In this study the production function approach is used with the inclusion of technical efficiency measurement from the linear programming frontier production function which is expected to give unbiased input-output coefficients and greater statistical power in hypotheses testing, and can be related to various factors contributed in the differences in technical efficiency.

The result of this study of efficiency can be related to the dynamic element of farmers' behavior in the adjustment to the transition process of most farmers as in developing countries of Asia. This process includes technological and more importantly significance was institutional from the traditional-input exchange and sharing character toward more commercial and productivity oriented in the use of non-traditional input. There have been several studies on this kind of character ini Java, such as Geertz's agricultural involution, Suwardi's more rational larger farmers, Collier's *ani-ani-bawon* system, and Hayami-Kikuchi's non relationship of sickle-wage system. This study can be completing in identifying this further process to the more general of the use of non traditional input of factor in comparison to the use of traditional inputs of human labor and draught animal.

Abstrak

Masalah beras di Indonesia tidak hanya penting karena beras merupakan bahan makanan pokok, sumber gizi utama dan karena adanya kekurangan produksi selama beberapa dasawarsa, melainkan juga karena pengaruh dari harganya terhadap laju inflasi dan stabilisasi ekonomi. Berhasilnya revolusi hijau di Indonesia berkaitan erat dengan program Bimas yang selalu disempurnakan.

Studi ini mempelajari efisiensi produksi usahatani padi dari segi ekonomi mikro terutama berurusan dengan perilaku petani dalam optimasi produksi dan efisiensi teknis dalam hubungannya dengan teknik bertani dan faktor sosioekonomi.

Dalam analisis efisiensi teknis digunakan pendekatan dengan fungsi produksi frontier yang didapat dengan teknik *linear programming*. Dengan memasukkan pengukuran efisiensi teknis dalam analisis regresi, yang dimaksudkan juga untuk mencerminkan faktor management maka dihasilkan suatu fungsi produksi yang lebih baik dalam analisis regresi ini : pertama koefisien tidak menyimpang (*unbiased*) dan kekuatan statistik dalam pengujian hipotesis menjadi lebih besar. Penyimpangan manajemen (*management bias*) dari koefisien *input* dalam fungsi produksi dapat dihubungkan dengan penggunaan faktor-faktor produksi antara lain menghasilkan tiga hal : (1) bahwa tidak ada hubungan terbalik antara produktivitas dengan luas usahatani di daerah penelitian, (2) bahwa petani tidak selalu menggunakan pupuk pada tingkat efisiensi teknis yang tertinggi, dan (3) bahwa mekanisasi selektif seperti traktorisasi secara teknis tidak lebih efisien daripada cara tradisional (tenaga manusia dan hewan).

*)Department of Agricultural Socioeconomics, Faculty of Agriculture, Gadjah Mada University, Yogyakarta Indonesia.

Teknik bertani dan faktor sosioekonomi yang berhubungan erat dengan efisiensi tehnis adalah pemupukan terakhir yang terlalu lambat, penggunaan alat penyiang yang teknis kurang efisien, pekerjaan di luar usahatani yang mengurangi efisiensi teknis, dan pendapatan dari luar usahatani yang meningkatkan efisiensi teknis, sedangkan faktor-faktor lain lebih bersifat setempat atau musim tertentu.

Dari analisis efisiensi harga atau efisiensi alokasi sumberdaya ditemukan beberapa hal yang tidak selalu sesuai dengan penemuan-penemuan terdahulu dengan metode pendekatan yang berbeda. Pertama dalam penggunaan *input* modern pupuk ternyata petani tidak selalu menggunakan pada tingkat optimum karena keterlambatan dalam menyesuaikan terhadap keadaan teknologi dan harga relatif yang selalu berubah.

Kedua dalam penggunaan tenaga kerja manusia petani di daerah penelitian berperilaku seperti petani lain di Asia dengan tekanan kepadatan penduduk, yaitu dengan proporsi yang besar pada penggunaan tenaga kerja di luar keluarga dalam suatu sistem pertukaran tenaga kerja dan saling menikmati hasil (*labor exchange and income sharing*). Hal ini ternyata merupakan ciri kelembagaan tradisional yang kuat dalam penggunaan input tradisional, termasuk juga tenaga hewan untuk usahatani. Proses perubahan terjadi dalam modernisasi pertanian ini tidak hanya secara teknologi melainkan juga perubahan kelembagaan ke arah lebih berorientasi pada produktivitas dan komersial, terutama didorong oleh adanya introduksi penggunaan input non tradisional seperti penggunaan traktor.

Introduction

Rice is a very important commodity in Indonesia, as in most Asian countries, not only because it is the main staple food and the main source of nutrition intake, but also because of the shortage of domestic rice supply for several decades and the influence of its price on the inflation rate and economic stabilization.

The success of the green revolution in Indonesia is closely linked with the expansion of the continuously improved *Bimas Programme* and the input and output price policy. Since the initial year of first adoption of IRRI varieties (IR 8 and IR 5) in 1967 rice production has increased at high rate of more than four percents (table 1) and rice self sufficiency, which has been a major policy since the Kasimo Welfare Plan (1951 — 1956), seemed that it would be able to be achieved and has targeted in each *Pelita* (five year development plan), but various problems were recognized i.e., the adoption process, the brown plant hopper attact etc.

The problems in increasing rice production were not only technological, but also it depend on irrigation infra structure and socioeconomic factors. Biological and chemical technology which is land saving character that was most developed in irrigated lowland ith high population density in Java and Bali.

One of the socioeconomic problems in dealing with small farmers in Indonesia refers to the Geertz's paradigm of agricultural involution in Java (Geertz 1963), that due to the Dutch colonial policy, at the beginning of the independence, farmers were still in limited creativity and only be able to increase production as much as the growth of population without any improvement on level of living. That is why the first stage of the development of *Bimas* was to break this condition through the larger farmers. Therefore there were different impact of the intensification program at the first stage with the most benefit going to larger farmers (Suwardi, 1972, 1973, Sinaga & Collier 1975, Sayogyo 1973), but then there was a tendency of increasing yield as farm size smaller (Keuning 1984).

There are phenomena that in developing countries few farmers are fully exploiting the potential of rice production technology, and therefore the actual yields of rice farms are far below their potential (Herdt & Wickham 1978). There are two kinds of yield gaps according to Gomez *et al* (1979) (figure 1) : (1) between experiment station and potential farm yield, and (2) between potential and actual farm yield. The gap I exists mainly because of environmental differences between experiment station and the actual rice farms. It shows that technology in farm condition does not give the yield as high as in experiment station or might be the technology is not transferable. The gap II exists becausefarmersuse inputs and cultural practices that result in lower yield than those possible on their farms. It concerns the biological and sosioeconomic constraints. Barker (1979) stated that this gap can be partitioned in three segments (figure 2) : (1) the segment due to the profit seeking behavior reflects the difference between maximum yield and maximum profit, (2) price or allocative inefficiency is the failure to maximize profit, and (3) technical inefficiency is the failure to produce on most efficient production function.

In summary, those influencing the farm rice productivity can be related to (1) physical environment, (2) irrigation, (3) input level, (4) cultural practices or farming techniques, and (5) sosioeconomic factors. Therefore this tudy concerns with factors which influence and contribute to higher rice production efficiency, mainly from the point of view of microeconomics. Factors associated to the problems in increasing farm rice production efficiency will relate to (1) farmers' economizing behavior or the successfulness of farmers as profit maximizers in using various inputs i.e. modern input and labor, (2) factors contributing in technical efficiency which determine farmers production i.e. farming techniques or cultural practices and managerial ability, and (3) sosioeconomic factors influencing technical efficiency.

The first concerns with the successfulness of farmers as profit maximizers. It relates to dynamic element of producer behavior or short run economic efficiency in the process of changing technology and relative price. The second is concerning the technical efficiency that is output per unit of inputs where inputs are aggregated. Many rice farming techniques are difference among locations and among farmers. Improving these practices usually does not increase much the cost of production. The study of technical efficiency is an important aspect of the study of development, because it quantifies the productive contributions of factors that are not easily amenable to measurement.

Analytical Approach

2.1. The Production Function

Cobb-Douglas type of production function were employed in the OLS (ordinary least square) regression analysis, as :

$$Y = A \prod_{i=1}^{m} X_i^{B_i} + \varepsilon \quad \text{or} \quad \log Y = a + \sum_{i=1}^{m} B_i \log X_i + \varepsilon$$

where Y is output, X_i is i-th input, and B_i is the coeficient of i-th input. This OLS production function from cross-sectional data without any inclusion of management factors may have bias in the input coefficient due to the different input level between farmers with higher managerial skill or technical efficiency and farmers with lower managerial skill or technical efficiency (Yotopoulos & Nugent 1976). Therefore it is better to include management factor in this kind of analysis as :

$$\log Y = \log a + \sum_{i=1}^{m} b_i \log X_i + cM + \varepsilon$$

where M is management factor and c is the coefficients of management variable. The comparison between the input elasticity coefficient with and without management factor is used to test the management bias of these coefficients, as :

$$cd_i = E(B_i - b_i)$$

The sign of this bias can be related to correlation between input level and the better management or technical efficiency. The management factor of cM can be regressed then to be rellated to various factors of farming techniques and socioeconomic.

2.2. Measurement of Technical Efficiency

In identifying whether there are differences in management or technical efficiency among rice farmers, it needs to quantify the technical efficiency or this management component (M). There are three different approaches to this problem : (1) by grouping the sample farmers based on a criterium such as tenurial status, farm size and the using dummy variable, (2) developing a score or index as a proxy based on selected criteria such as education, information, modernization etc., and (3) by using frontier production function.

2.3. Frontier Production Function

A frontier production function is a production function that is technically most efficient in the sense that their point are in the production possibility set, and there is no way to obtain more output than despicted by this point without using more input. Some farms will be better able to produce than other farms because they have better skill and better endowment, they have better production possibility set.

Frontier Production Function

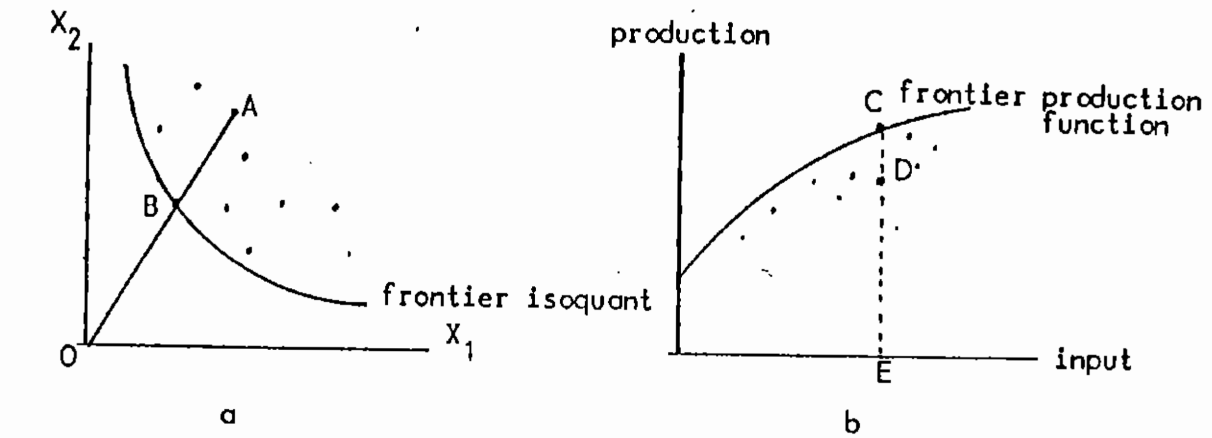

Figure 3. **Frontier Production Function**

The frontier production function is the maximum production possibility set or the maximum feasibility productivity under farm condition. The frontier production function is operationalized through Farell model (Farell 1957). In case of two kinds of inputs of X_1 and X_2 (fig. 3a) the frontier isoquant will be the highest production (closest to the origin of 0) in each input combination, or the highest production on frontier production function of figure 3b. Some farms may be on the technically efficient frontier production function as point B or C, while others lie varying distance away from it (Farell 1957, Timmer 1971). The technical efficiency rating (TER) is OB/OA of fig. 3a or ED/EC of fig.3b. This means that TER is the ratio between actual productivity and the potentially highest productivity. Or in other words the technical efficiency is output per unit of input where inputs are aggregated in some manner. Or it is also often called the total factor productivity.

This frontier production function as the maximum production possibility set is always have higher or at least equals to the observed actual production for the same level of input use. One of the methods in estimating this frontier is by using linear programming method as :

$$Y_i = AX_{i1}^{b_1} X_{i2}^{b_2} \ldots\ldots X_{im}^{b_m} E_i$$

or in logarithm,

$$y_i = b_o + \sum_j b_j x_{ij} + e_i$$

If e_i are constrained to one side of estimated production surface the resulting function is an envelope or frontier function. The equation is estimated as :

$$\hat{b}_o + \sum_j \hat{b}_j x_{ij} = \hat{y}_i \geqslant y_i$$

By setting all $e_i \geqslant 0$, the equation can be written as an equality

$$\hat{b}_o + \sum_j \hat{b}_j x_{ij} - \hat{e}_i = y_i$$

The linear programming technique of estimation is to minimize $\sum_i e_i$ subject to :

$$\hat{b}_o + \sum_j \hat{b}_j x_{ij} \geqslant y_i \qquad (i = 1, 2, \ldots, n)$$

$$\hat{e}_i = \hat{b}_o + \sum_j \hat{b}_j x_{ij} - y_i$$

$$\sum_i \hat{e}_i = n\hat{b}_o + \sum_i \sum_j \hat{b}_j x_{ij} - \sum_i y_i \qquad \text{devided by n}$$

$$\frac{\sum_i \hat{e}_i}{n} = \hat{b}_o + \sum_j \hat{b}_j \bar{x}_j - \bar{y}$$

where $\overline{x}_j$ and $\overline{y}$ are the means of each input and output (in logarithm), respectively. Since n and $\overline{y}$ are constant the Linear Programming structure is :

$$\text{minimize} \quad \hat{b}_o + \sum_j \hat{b}_j \overline{x}_j$$

$$\text{subject to} \quad \hat{b}_o + \sum_j \hat{b}_j x_{1j} \geq y_1$$

$$\hat{b}_o + \sum_j \hat{b}_j x_{2j} \geq y_2$$

$$\vdots$$

$$\hat{b}_o + \sum_j \hat{b}_j x_{nj} \geq y_n$$

Technical efficiency of each sample is measured with the frontier production function. The ratio of the actual production of farm i (Y_i) to the estimated production of farm i ($\hat{Y}_i$) from the frontier function estimate gives the technical efficiency rating (TER) of farm i,

$$TER_i = Y_i/\hat{Y}_i$$

In order to avoid the problem of spurious errors in the extreme observation, Timmer (1971) suggest fitting a probabilistic frontier, in which equation :

$$b_o + \sum_j b_j x_{ij} = \hat{y}_i > y_i$$

must be translated into a probability statement as

$$\Pr[(b_o + \sum_j b_j x_{ij}) > y_i] > p$$

where p is an externally specified probability (e.g. 98%) for which the inequality is to hold. The value of p will be obtained by deleting a percentage of observation on the assumption that they were affected by statistical error, e.g. by deleting 2% of observations which are most efficient (Timmer, 1971).

Data

This study utilized primary data from intensive study conducted in several villages of rice producing areas in West Java and Yogyakarta. The main data were from the study that was conducted by a research team studying rice farming in Indonesia that consisted of Japanese scientists and Indonesian in 1983 and 1984 in West Java and in 1980, 1981 and 1982 in Yogyakarta, where the writer joins this team and actively participate in this activity. Two cases of villages in West Java were Rancaudik and Rancaekek Wetan. Rancaudik village was located in the main rice producing area of the north coastal plain area of West Java which was well irrigated. Rancaekek Wetan village was located in the rice producing area of the high plain of Bandung which was also well up to moderately well irrigated. Gadingsari village of Yogyakarta was located in the south lower plain of rice producing area of Yogyakarta with good irrigated lowland rice field.

The data in West Java covered 1982 dry season and 1982 — 83 wet season of rice farming, but in Rancaekek Village the 1982 dry season data could not be analyzed because of the harvest failure due to the volcano ash of the Galunggung eruption. There were 98 samples in Rancaudik village and 93 samples at Rancaekek. The data of Gadingsari village covered 1979 dry season and 1979 — 80 wet season. There were 30 samples rice farmers that grew rice mostly at least twice a year and some three times a year.

Other data were collected in the farm survey and farm-field experiment of IRRI constraint project in 1974 — 77 and other data of similar research conducted by Gadjah Mada University in which the writer was the leader of the research teams, up to 1981. These data especially dealt with production and current inputs and some other data that were used for different variables. The experimental data were from experiments on farmers' fields that meant to simulate the actual farm condition and practices that would be able to approximate the input-output relationship on actual farm.

Technical Efficiency and Management Bias

In estimating the production function four equation models are developed and the best model was tried in several level of probabilistic frontier production functions and the OLS regression production functions. And the best probabilistic level was selected for each village and season for further analysis.

The analytical results show that the technical efficiency rating (TER) coefficients in the production functions always have high magnitude and high level of significancy through all seasons and locations, that means that there were great variations on the technical efficiency among individual farmers beyond the input effect (table 2). The average TER ranged from 0.7366 at Rancaudik 1982 — 83 wet season up to 0.8653 at Gadingsari 1979-80 wet season (table 3), that means that 14 — 26% below their potential productivity that technically could be obtained. This problem of various degrees of technical efficiencies of farmers can then be related to factors of farming techniques and socioeconomic.

The management bias, the difference between input-output coefficients of production function which excludes and includes technical efficiency (tabel 4) introduce some phenomena. Most of the signs of the land coefficient bias are positive, that means that most of better farmers used more land input to produce higher level of productivity, except at Gadingsari 1979 dry season. This indicates that larger farmers were mostly better farmers in the sense with higher level total factor productivity. It shows that in this study area there was not characterized by an inverse relationship between size and productivity, that might be due to the more available off-farm employment opportunity since 1979. This result does not mean to be rejecting the size-yield inverse relationship paradigm in developing countries, because the total factor productivity does not always coincide with the single factor productivity of land resource (yield).

The level of fertilizer application at Rancaudik 1982 — 83 wet season rice farming with geometric mean of 349 kilogram per hectare technically the efficiency could still be increased by rising this fertilizer application. But for Rancaudik 1982 dry season and Rancaekek 1982 — 83 wet season with higher level of fertilizer applications of 381 and 403 kilograms per hectare of geometric means, respectively, technically the efficiencies could be increased by reducing the level of fertilizer applications. However at Gadingsari 1979 dry season although the geometric mean was higher that the wet season the higher level of fertilizer application might still produce a slightly higher technical efficiency. It seems here that in the study area the level of fertilizer application was not always at the appropriate level technically.

In 1982 — 83 wet season at Rancaudik and Rancaekek, technically, it was not more efficient in rice production to mechanize the land preparation like in many places in Asia (Duff & Kaiser, 1982 p.27). However, at dry season the use oftractor was related to higher technical efficiency. It might be due to the labor availability problem in dry season.

Farming Techniques

The farming technique variables which are almost uniformly successful in explaining variation in this relative technical efficiency among farmers are number of times of fertilizer top dressing and the use of weeder tool, while other variables are rather seasonal and locational specific. The negative effect of more frequent fertilizer application relates to the late application of the last dressing after tillering stage of the rice plant growth.

The technical inefficiency of the use of weeder seems to be a general problem in the mechanization of small farms in less developed countries as the use of tractor in land preparation. While off-farm employment happened to increase in rural Java this simple mechanization that had been adopted widely in certain villages, in facing the labor problem, is one of the way out to maintain rice production, and the next is how to increase weeder-weeding efficiency technically.

Other farming techniques such as times of weeding, plantsper hill, age of seedling, and the use of fertilizer at nursery, in general were not problems anymore and not significantly related to technical efficiency due to the high intensity and wide adoption of these practices, except in some particular season and locations that has not adopted widely the may still contribute to higher technical efficiency. The weeding had been done at the level of necessarily intensive at twice or three times that more times of weedings mostly would not significantly affect technical efficiency, except for the 1982 — 83 wet season rice farming at Rancaudik that twice weedings seemed still need to be done more to higher techical efficiency.

Most farmers transplanted 2 — 3 seedling per hill and this existing practice seemed quite alright in relation to technical efficiency, except at Rancaekek where more seedling per hill might increase technical efficiency. Most seedlings at Rancaudik and Gadingsari were transplanted around the recommended age of 20 — 25 days, therefore it was not a problem in technical efficiency, except for Rancaekek that this significant effect of seedling age relates to the water availability problem. The use of fertilizeroat nursey and at basal were not problems anymore due to the wide adoption of this practice.

Socioeconomic Factors on Technical Efficiency

Management can relate to technical efficiency, therefore some research tried to measure the technical efficiency in the form of indexes of factors that are expected to be related to management capability. In this study the logarithm of TER (technical efficiency rating) are regresed on a number of socioeconomic factors with assumption that there are neutral shift on the production function. The individual village and season frontier production function are used in the measurement of technical efficiency, and pooled data analysis and covariance methods are also tried since the TER has reflected the specific character of each village and season.

There are some socioeconomic factors that are significantly related to technical efficiency for Rancaudik and West Java (Rancaudik + Rancaekek) covariance method, especially the variables of off-farm employment, off-farm income and education. The off-farm employment and income in the study area were important source of income that most farmers spent their time on off-farm activities. Most of off-farm income was from farmers' off-farm job, the second was from wive's off-farm job, and some was from other members of household.

The off-farm employment significantly relates to lower technical efficiency especially at Rancaudik 1982 — 83 wet season. It means that at Rancaudik with relatively larger farm size than Rancaekek and Gadingsari, the rice farm operation seemed need more attention especially at wet season, that the number of days spent off-farm, whether by farmers or wives, made them lack the time to look after the important details of farm management. While at Rancaekek and Gadingsari with smaller farm size the off-farm employment was not clearly related to technical efficiency. The explanation is that the positive effect of off-farm activities due to better information which would help them in making adjustment in farm operation, counters that negative effect, and the farm operation on smaller farm need less times to carry out.

The total off-farm household income relates to higher technical efficiency especially supported by Rancaudik analytical result that farmers with higher income might have better chance in acquiring the various inputs for the farm at the time they are needed. The analytical results of Rancaekek and Gadingsari do not clearly support the positive effect of off-farm income on technical efficiency. The smaller farm size in these villages might not need more finance badly and the additional income referred not for farm operation.

The off-farm activities of wives always have the same effect as the off-farm activities of farmers, that means that the role of farmers' wives in rice farming were at leat as important as farmers themselves, and in fact the role of wives as source of off-farm income was almost as important as farmers.

The older farmers' age tends to be negatively related to technical efficiency at Gadingsari reflects the relative activity of younger farmers in comparison to the older farmers. But at Rancaudik and Rancaekek younger farmers undertook more off-farm job so that the older farmers had more time to do farm operation and management that made them not at lower technical efficiency.

The percentage of rented in lowland happened to be almost consistenly negatively related to lower technical efficiency, except at Rancaekek, although same are not significant or significant at low level. While recent studies on tenancy empirically found out the equal productivity and efficiency of share cropping tenancy in comparison to ownership and other tenurial contracts. And the fact that share-cropping tenancy was very common at all studied villages. There were indication that this tenancy variable had significantly positive correlation with off-farm employment. One possible explanation refers to the effect of off-farm employment on technical efficiency. The other is that the lower technical efficiency of tenant farmers might relate to lower quality of land as found in the study in philippines (Mandac & Herdt, 1978).

In general the general school education is consistently related to higher technical efficiency and on the covariance method of Rancaudik & Rancaekek this variable of education significantly related to higher technical efficiency. This coincides with most of the studies in Asian countries, that support the Huffman argument of worker effect (Huffman, 1974) that more educated worker produces more output from a given bundle of inputs.

Price Efficiency of Modern Input

The studies of price of allocative efficiency of the production resource in the framework of static equilibrium analysis has been a popular field of research for agricultural economist, particularly the attention has been focused on examining the hypotheses of Schultz (Schultz, 1964) of the efficiency allocation of factor of production in traditional agriculture, by using a Cobb-Douglas type of production function and testing the equality of marginal productivity at geometric mean to the opportunity cost. Most studies indicated the succesfullness of farmers as input allocators and some the unsuccessfullness of farmers as input allocators.

Most of the failure in rejecting the null hypotheses of that equality of marginal value productivity to input price were determined by the smaller magnitudes of in put-output coefficients and the greater standard errors of these coefficients. In this study, by introducing an technical efficiency index (TER) that is to be able to eliminate management bias, the input-output elasticity coefficients come out to be difference in magnitudes with higher significancy due to the smaller standard errors of these coefficients. And the results come out with mostly difference from most of previous studies. It is because that most of the studies of allocative efficiency did not include management factor or technical efficiency variable in the production function using cross-sectional data, or they might include in such forms of dummies or indexes as proxies to management factor that is quite not enough to explain the whole variation in output among samples, and it was reflected in the lower coefficient of determinations. The inclusion of appropriate measurement of management factors of technical efficiency that is to be able to explain the output variation better introduces higher statistical power in hypotheses testing in two ways, by changing the magnitudes of input-output elasticity coefficients to be without management bias and by reducing the standard errors of these coefficients.

An alternative methodology in the study of allocative efficiency is using profit function approach, because there is a simultaneous bias in the independent variables of OLS regression of production function in the study of allocative efficiency. And almost all studies by using this approach gave the results that farmers were allocatively efficient. However, the use of cross-sectional price data in profit function analysis faces some problems (Quiggin & Bui-Lan, 1984) that not only most of price coefficients are not significantly difference from zero but the absence of price variation will make the estimation of profit function impossible and the heterogeneity of input quality as source of input-price variation will become a serious problem as in the price of pesticides.

It seems that the work on profit function in using cross-sectional price data for the study of allocative efficiency has been not quite satisfying. If the price variation is not sufficient the approach based on production function is better to be used. The use of production function approach with the inclusion of TER as a more appropriate measurement of management factor or technical efficiency produces that farmers in short run were not using modern input at optimum level (table 7). The unsuccessfulness of farmers in the short-run profit maximization relates to the lag adjustment of the farmers to the continuously changing biological technology of modern varieties toward more fertilizer responsive ones and continuously declining input-output price ratio since 1972. This inefficiency of farmers as input allocators in a rapidly changing technology and relative price does not mean to be rejecting the hypotheses of Schultz, since the Schultz's efficient farmers were in the traditional agriculture with stagnant technology where the farmers were intuitively aware of resource allocation that embodied in cultural knowledge transmitted from generation to generation.

The Economic Rationality of the Use of Labor Input

A densely populated economies such as Java would rather make people relate to dualistic theories, but recent approach in labor theory has emphasized that labor force behavior can only be adequately be understood in the context of household decision making and the factors that determine the allocation of time of various household members among a rage of activities, that is called the theory of firm household complex. This theory has been developed by Nakajima (1969) and recently by Dawson (1984) based on subjective equilibrium of the firm household complex that essentialy income-leisure model in traditional text in economic theory with the difference that income function has the shape of production function of labor input. The economic behavior of family farm in using family labor is rational when the farm family has achieved subjective equilibrium in maximizing its utility function subject to income function which implies that the marginal productivity of labor equals the marginal valuation of family labor. But as soon as there is labor market the marginal valuation of family labor will equal the market wage rate which implies that the family farm is maximizing profit and the marginality condition of profit maximization must be satisfied.

In the study area there was no pure family farm that is only using family labor, regardless how small the farm was. Hired labor had a quite high proportion in total labor utilized (table 8) especially in harvesting, transplanting, and weeding, which required more precise timing that was difficult to be carried out by family labors only. While family labor were mainly used for continuous care such as water control which was purely using family labor only, and other task of pest control, fertilizer application, and nursery works. This high dependency on hired labor is comparable to other findings on small farms in several places of Asia (Hartz 1980, Hayami 1978 P. 28 — 30), that farmers employed each others in their farm operations as a kind of labor exchange with wage payment.

From those theory developed above, theoretically the test of economic rationality of the family labor used on family farm with labor market is inseparable from the total labor used including hired labor. While at Rancaudik 1982 — 83 wet season labor was optimally utilized, at Rancaekek and Gadingsari with relatively small farm size, based on market prices, labor were over utilized, more that economic optimum (table 9).

These analytical results would make people think that farmers at Rancaekek and Gadingsari were not rational in utilizing their labor, not only family labor because there were more hired labor in the labor input. The explanation is that the farmer's valuation on output and input did not equal the market prices. This would violate the existence of competitive market for input (labor) and output (rice). In fact there were labor market and rice market, but the labor market in farming and non farming might not provide equal employment opportunity to each villager. Different work opportunities require different skills and farming skill is the most appropriate for works in farming. At Rancaekek and Gadingsari farmers utilized more labor including hired labor that means they had to pay the labor, in the Hayami's system of labor exchange with wage payment. Even their income was reduced by the amount paid to neighbors the reduction would be compensated by the family's wage earning from neighbors.

The second explanation on output site is that the subjective marginal value product did not equal the market price of rice due to the small farm size with small amount of rice product. The farmers' valuation on output of rice as the main staple food seemed much higher than market price. They did not sell their rice unless in a badly needed for cash to buy other needs. It was reflected in that at Rancaekek most farmers did not sell their rice product, even some rice farmers bought rice for their home consumption, while at Rancaudik with relatively larger farm size almost all farmers sold large part of their rice product. So at Rancaekek the rice farmers are closer to subsistence-production part time rice farmers, while at Rancaudik farmers are more commercial in rice production.

The conclusion is that rice farmers in the study area behaved as other small farmers in most densely populated areas in a common system of high dependency on non family labor in a kind of labor exchange based on tradition in the village community that family labor can not be separately regarded out from the whole labor used. The subjective valuation on family labor will be the same as a common valuation of labor used by the people in the village. Although theoretically the existence of labor market will make family farm satisfy the marginality condition of profit maximization, the close labor market in one locality (may be in one village) make the common valuation on labor would be difference from the wage rate, since the wage earning and wage payment is a kind of exchange of labor and income sharing.

The Input Substitution of Human Labor, Animal, and Tractor

In Indonesia there has been relativiely little mechanization in land preparation, but in certain area of highly densely populated rice producing area in north coastal plain of West Java hand tractor and four-wheeled mini tranctor had been adopted. The traditional methods in land preparation were those by using draught animal and/or human labor, and recently seemed to be in transitional process to the use of tractor. This transition was more advanced in the north coastal plain of Rancaudik village especially in displacing the use of draught animal, being reflected by no animal input in this village in 1982 — 83 wet season rice farming and only 1.6 persent in 1982 dry season. And in both the dry and wet season this tractor input had been used at allocatively optimum level (table 10), better than the labor use in 1982 dry season that more scarce.

The more complete and more complicated process of this transition was found at Rancaekek village where human labor, draught animal, and tractor were mixed in doing land preparation in a variety of combinations. Due to this complicated transition there were complete measurement on this input subtitution of all the three kinds of inputs, to find out that all of them were not used optimally but in such different levels of allocative efficiencies. Labor was used beyond the optimum level, while tractor was used below and animal farther below the optimum levels. Therefore draught animal could profitably subtitute both of other inputs, while tractor could profitably substitute labor, but the scarcity of draught animal constrained its higher use and the adoption of tractor in this village seemed to be still in earlier stage than at the north coastal plain of Rancaudik.

At Gadingsari in 1979 — 80 there was no tractor used for land preparation. the scarcity of draught animal and the relatively small size of rice farming made the farmers use more human labor in land preparation, although the use of draught animal could profitably substitute human labor, but the more and more scarce of this animal input had constrained the higher use of this input while the price (the service price) did not reflect the real scarcity rather to the common valuation in rural community considering that the animal owners might not quite commercial as the tractor owners and the hired draught animal might have the character as human labors in a close market of a locality charactirized by labor exchange with wage payment. This explanation also hold for the Rancaekek case that the scarcity of draught animal of buffaloes and caws should be reflected in the competitive price but the influence of rural institution is the explanation.

The conclusion is that the increasing scarcity of draught animal and the smaller size of farm have made the farmers use more costly human labor in this rural community characterized by labor exchange included draught animal exchange so that the price did not reflect the real scarcity or abundancy of these inputs. Therefore the input substitutions were not always allocatively efficient. This was consistent with the farmers' lag adjustment in the use of input in the condition that there were changes in technology and relative prices. In this input substitution the draught animal price (the service price) was also lagging in adjusting to the increasing scarcity due to the labor exchange characters.

Conclusion

There were gaps between the average actual farm productivity and the potentially achievable productivity in experiment stations. These gaps concern with various factors : physical environment, irrigation, input level, farming techniques, and socioeconomic factors. But it is more appropriate to consider the economically recoverable gap or economic slack. This problem deals with economic behavior of the farmers, and managerial skill and ability of the farmers those are reflected in technical efficiency.

By using probabilistic LP frontier production function for the measurement of technical efficiency, this study shows that there were great variation in technical efficiency among individual farmers beyond the input effect. Therefore the inclusion of appropriate measurement of management factor on technical efficiency in the production function estimation from the regression analysis of cross-sectional using data will produce better estimate of production function with unbiased input coefficients. And this management bias itself can explain the relation of input level and technical efficiency, such as that there was no size-productivity inverse relationship, inappropriate technical level of fertilizer application, and the inefficient mechanization in land preparation.

The second advantage of the inclusion of technical efficiency in production function analysis is the greater statistical power in hypotheses testing on price efficiency due to the smaller standard errors of the input coefficients, such as the unsuccessfulness of farmers in short run profit maximization relating to dynamic element of farmers' behavior in adjustment to the changing conditions.

The third advantage is that this index of technical efficiency can be used for the analyses of factors those hypothized to be related to technical efficiency or managerial factor such as farming techniques and socioeconomic factors. Some of the example results are the inefficiency of the late of the last application on of fertilizer, the inefficience of the use of weeder tool, and other farming techniques those were locational and seasonal specific. Sosioeconomic factors of off-farm employment, off-farm income, and farmer's age are other examples those were related to technical efficiency or management factor.

Other important point resulted from this study relating to the typical small rice farmers in Asia and mainly in Java is that the rice farmers in the study area of lowland of Java behaved as other small farmers in most densely populated areas in Asia in a common system of high dependency on non family labor with a common subjective valuation on labor that was not necessary equal to the wage rate, since the wage earning and wage payment are a kind of exchange in labor and income sharing. This village institution can also be used to explain the inefficience of the input substitution between draught animal and labor.

Inspite the exitence of the institution of rural community in Java it seems that the Geertz's paradigm of agricultural involution in Java not to hold anymore in the last two decades, not only as found in Suwardi's theses that was rejecting throught the larger farmers, but almost all farmers including smaller farmers have benefited the green revolution by adopting modern rice technology being reflected in the high rate of growth in rice production more than the population growth.

In fact all farmers in the study area as rice farmers in Java in general with strong population pressure recently were familiar and adopted land-saving modern rice production technology such as modern varieties, chemical fertilizers, pesticides, and improved cultivation techniques, while mechanical technology such as tractor using in land preparation had been adopted in a limited area and seemed in the initial process of mechanization in a densely populated area. However, there were still problems in relation to social and economic structure and actual cultivation techniques.

Inspite the wide adoption of modern rice technology in Java the inefficient level of application of this modern technology and the wide variation of farm rice productivity show that the rice farmers in Java were in the dynamic process of modernizing agriculture, not only technological but also social institutional.

The institutional aspect of this process deals with the existence or relatively strong institution in the original character of mutual exchange and sharing in the traditional input use being reflected in the imperfect and close market of labor and draught animal and the common valuation of labor and draught animal in village locality.

The labor-saving effect of tractorization means to reduce wage earning opportunity for many landless laborers in the village, but since there have been increasingly greater off-farm employment opportunities, it is expected not worsen the income distribution, and this tractorization is promoted by the shortage of labor in the peak season. This selected mechanization of tractorization is not only an example of transition process from the development based on land-saving technology to the selected labor saving technology in densely populated area, but also a changing process of a community with strong institution of mutual echange and sharing in using traditional input to the commercial profit-oriented farming in using modern input.

The institution change will be introduced when the resulting gain is expected to exceed the cost, and the process of this change implies disequilibria due to the inflexibility of market in reallocating resources in response to the relative scarcity adjustment in the common subjective valuation of labor and animal input in Java. However, this changing process toward more commercial oriented seemed would be positively affected by the availability of alternative method of non traditional input of land preparation of tractor using. Inspite the process toward more productivity oriented the spirit of the original institution character of mutual help and sharing is still expected to exist without disturbing the productivity oriented.

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Table 1. **Area, Production, Yield, Import, Per Capita Availability of Milled Rice, And Growth Rate in Indonesia, 1968 — 82**

Year	Area (1000 ha)	prod. (1000t)	Yield (t/ha)	Import. (1000 t)	Prod + Imp. (1000)	Per cap (kg)
1968	8,021	11,666	1,45	486	12,152	108.2
1969	8,104	12,353	1.54	238	12,591	109.6
1970	8,135	13,451	1.62	324	13,775	117.2
1971	8,324	13,723	1.65	120	13,843	115.2
1972	7,897	13,182	1.67	335	13,517	109.9
1973	8,403	14,607	1.74	1,863	16,470	130.8
1974	8,509	15.276	1.80	1,132	16,408	127.3
1975	8,495	15,185	1.79	692	15,877	120.4
1976	8,369	15,845	1.89	1,301	17,146	127.0
1977	8,360	15,882	1.90	1,973	17,855	129.2
1978	8,929	17,525	1.96	1,841	19,366	136.8
1979	8,849	17,872	2.02	1,910	19,828	136,9
1980	9,000	20,163	2.24	2,000	22,163	149.4
1981	9,380	22,286	2.38	480	22,766	149.9
1982	9,020	22,837	2.53	300	23,137	148.8
1983	8,960	23,961	2.67	1,160	25,121	157.8
Compound Growth Rate (%)*						
68 — 74	1.00	3.77	2.77			
74 — 80	1.02	5.03	4.01			
68 — 80	1.01	4.45	3.44		4.85	2.44
80 — 83	0.72	7.70	6.98			
68 — 83	0.91	4.88	3.97		4.95	2.46

* Compound growth rate of three year moving averages
Compound growth formula :

$$G(Y) = \frac{1}{n} \sum_{t=1}^{n} \left(\frac{Y_t}{Y_{t-1}} - 1 \right)$$

G(Yield) = G(Prod) — G (Area)

Source : BPS (Central Bureau of Statistic).

Table 2. **The Coefficients of Linear Programming (LP) Frontier And OLS Regression Production Function**

	LP	OLS	LP	OLS
	Rancaudik wet season		*Rancaekek wet season*	
Constant	2.6127	1.2709	2.0318	1.4018
Land	.7363	.3486***	.6835	.6719***
Fertilizer	.1984	.3554***	.2612	.2435***
Labor	.0	.2026**	.0373	.0484**
Tractor	.0	.0666**	.0950	.1045***
Pesticide	.0	.0962*	.1053	.1301***
Animal			.1046	.1066***
TER		.6278*		.6377***
F-value		150.15***		3142.20***
R^2		.941		.999
	Gadingsari wet season		*Gadingsari dry season*	
Constant	2.0912	1.5552	2.2716	1.7258
Land	.6772	.6909***	.8009	.7998***
Fertilizer	.1503	.1657***	.0780	.0790***
Labor	.0630	.0110°	.0052	.0031
Pesticide	.0	.0138	.0	-.0113
Animal	.0324	.0352***	.0260	.0286***
TER		.5449***		.5578***
F-value		4139.96***		3302.52***
R^2		.999		.999

Note: *** significant at 1% level
** significant at 5% level
* significant at 10% level
° significant at 20% level

Table 3. **Technial Efficiency Rating (TER)**

	Minimum	Maximum	Mean	Coefficient of variation
Rancaudik 1982 — 83 wet season	.2672	1	.7366	.24
Rancaekek 1982 — 83 wet season	.4142	1	.7613	.27
Gadingsari 1979 — 80 wet season	.5818	1	.8653	.14
Gadingsari 1979 dry season	.5152	1	.8548	.15

Table 4. **The Production Function Elasticities Without and With Management or Technical Efficiency**

	Elasticity with TER excluded	Elasticity with TER included	Technical Efficiency Elasticity
RANCAUDIK 1982/83 w.s.			
Land	.4774	.3486	.1288
Fertilizer	.4233	.3554	.0679
Labor	.2147	.2026	.0121
Tractor	— .0219	.0666	.0885
Pesticide	.0267	.0962	— .0399
Sum of Elasticities	1.1202	1.0694	
Output Elasticity			.6278
RANCAUDIK 1982 d.s.			
Land	.6546	.1998	.4148
Fertilizer	.2639	.4265	— .1624
Labor	.0477	.4280	— .3803
Tractor	.0459	.0416	.0043
Pesticide	.0034	.0392	— .0358
Sum of Elasticities	1.0155	1.1351	
Output Elasticity			.7137
RANCAEKEK 1982/83 w.s.			
Land	.8605	.6719	.1886
Fertilizer	.1009	.2435	— .1426
Labor	.0104	.0484	— .0380
Tractor	.0384	.1045	— .0661
Pesticide	— .0685	.1301	— .1986
Animal	.0580	.1066	— .0460
Sum of Elasticities	.9997	1.3050	
Output Elasticity			.6377
GADINGSARI 1979/80 w.s.			
Land	.7017	.6909	.0108
Fertilizer	.0599	.1657	— .1058
Labor	.1011	.0110	.0901
Animal	.1138	.0352	.0786
Pesticide	.0324	.0138	. 0186
Sum of Elasticities	1.0089	.9166	
Output Elasticity			.5449
GADINGSARI 1979 d.s.			
Land	.7303	.7998	— .0695
Fertilizer	.0816	.0791	.0025
Labor	.0210	.0031	.0179
Animal	.0404	.0286	.0118
Pesticide	— .0411	— .0113	— .298
Sum of Elasticities	.8322	.8993	
Output Elasticity			.5578

Table 5. **Regression Analysis of Factors of Farming Techniques Associated With Technical Efficiency**

	Rancaudik			Rancaekek 82/83 ws	Rancaudik + Rancaekek
	82/83 ws	1982 ds	ws + ds		
Age of seedling				.0104** (2.533)	
Number time of weeding	.1443° (1.563)				
Number times of fertilizer top dress		— .0762* (— 1.823)	— .0612** (— 2.334)	— .1245*** (— 4.255)	— .0729*** (— 3.678)
Plant per hill				.0969* (1.755)	
Use of weeder at first weeding	— .3221*** (— 3.488)	— .1549° (— 1.390)	— .2111*** (— 3.035)		— .2101 (— 3.069)
Water problem		— .3677** (— 2.357)	— .1669** (— 2.093)		
Seasonal dummy			— .1021*** (— 4.184)		— 1.000*** (— 4.158)
Village dummy					.31245*** (4.399)
F-value	6.095***	3.631***	8.351***	6.534***	11.326***
R^2	.167	.160	.218	.346	.220

	Gadingsari		
	79/80 ws	1979 ds	ws + ds
Manure at basal dressing	.0844** (2.518)		.0668** (2.557)
Number times of fertilizer top dressing	— .0548*** (— 2.846)	— .0544** (— 2.248)	— .0533*** (— 3.547)
Use of weeder	— .0629* (— 1.813)	— .0673° (— 1.540)	— .0671** (— 2.480)
F-value	5.512***	2.963*	7.530***
R^2	.389	.180	.287

Note: t-value in parentheses
*** significant at 1% level
** sinificant at 5% level
* significant at 10% level
° significant at 20% level

Table 6. **Regression Analysis of Socioeconomic Factor Associated With Technical Efficiency**

	Rancaudik			Rancaudik + Fancaekek
	82/83 ws	1982 ds	ws + ds	
FOJ	— .00102*** (— 3.383)		— .00074*** (— 3.093)	
WOJ	— .00055*** (— 3.007)		— .00044*** (— 2.667)	
OFI	.00066*** (4.021)		.00041*** (2.818)	
TN		— .00088° (— 1.324)		— .00060** (— 2.020)
ED		.04611* (1.953)	.02537* (1.779)	.02690** (2.252)
Seasonal dummy			— .09892*** (— 4.044)	— .10101*** (— 3.863)
F.value	6.087***	2.581	6.643***	7.418***
R^2	.233	.082	.218	.121
Deg.of fr.	60	58	119	162

	Gadingsari		
	79/80 ws	1979 ds	ws + ds
AG (Age)			— .00150* (— 1.747)
TN (tenant)		— .00067° (— 1.671)	
ED (Education)		— .03563° (— 1.424)	— .02367° (— 1.431)
F-value		1.852	2.209
R2		.121	.072
Degree of freedom		27	57

Note: t-value in parentheses
*** significant at 1% level
** significant at 5% level
* significant at 10% level
° significant at 20% level

Table 7. **The Marginal Product of Modern Input And The Test of Allocative Efficiency**

Input	Geometric mean		Output elasticity	MP	s(MP)	Price ratio Px/Py	k_i
	Input	Output					
Rancaudik 1982/83 wet season							
Fertilizer	215.3	3153.6	.3554	5.206	.7512	.7465	6.9738**
Pesticide	5.990	3153.6	.0962	50.650	25.31	8.096	5.8247*
Rancaudik 1982 dry season							
Fertilizer	220.5	2452.5	.4265	4.744	.4537	.6985	6.7910**
Pesticide	4.918	2452.5	.0392	19.547	13.63	9.691	2.0171 ns
Rancaekek 1982/83 wet season							
Fertilizer	168.0	1554.9	.2435	2.253	.1178	.7107	3.1702**
Pesticide	3.867	1554.9	.1301	52.190	7.129	7.8864	6.6177**
Gadingsari 1979/80 wet season							
Fertilizer	76.47	384.86	.1657	.835	.0535	.4404	1.8963**
Pesticide	1.803	384.86	.0138	2.946	3.744	6.2909	.4683 ns
Gadingsari 1979 dry season							
Fertilizer	81.12	415.72	.0791	.405	.0550	.4375	.9266 ns
Pesticide	1.789	415.72	-.0113	-2.627	4.203	6.25	-6.0036 ns

Note : ** significantly different from unity at 1% level

* significantly different from unity at 10% level

ns not significantly different from unity at 10% level

MP = marginal productivity = b(Y/X)

Price ratio = input price/output price

s(MP) = standard deviation of MP = s_b (Y/X)

k_i = $MP_i(Py/Px_i)$

The t-test of k to unity is using $t_k = \dfrac{k-1}{s(MP)(Py/Px)}$

Table 8. **The Use of Family Labors And Hired Labors in Rice Farming at Rancaudik and Rancaekek in 1982/83**

	Rancaudik				Rancaekek	
	82/83 ws		1982 ds		82/83 ws	
	h.h.	%	h.h.	%	h.h.	%
Total labor	581.1	100	607.5	100	604.9	100
Family labor	150.8	25.9	155.6	25.6	187.9	31.1
Hired labor	430.3	74.1	451.9	74.4	417.0	68.9
Preharvest labor	446.2	76.8	473.4	77.9	519.4	85.9
Family labor	147.5	33.0	152.3	32.2	186.8	36.0
Hired labor	298.7	67.0	321.1	67.8	332.5	64.0
Harvest labor	134.9	23.2	134.1	22.1	85.5	14.1
Family Labor	3.3	2.5	3.3	2.5	1.1	1.3
Hired labor	131.6	97.5	130.8	97.5	84.4	98.7

Note : h.h. is human hours.

Table 9. **The Marginal Productivity of Labor And The Test of Labor Use Efficiency in Rice Farming**

Village & season	Geometric mean		Output elasticity	MP	s(MP)	Price ratio Px/Py	k
	Input	Output					
Rancaudik ws	534.0	3153.6	.2026	1.197	.522	.6638	1.8025-
Rancaudik ds	345.3	2452.5	.4280	3.040	.461	.7283	4.1740*
Rancaekek ws	610.9	1554.9	.0484	.123	.051	.9516	.1295*
Gadingsari ws	48.03	384.9	.0110	.088	.065	2.8309	.0311*
Gadingsari ds	50.19	415.7	.0031	.026	.073	2.8125	.0091*

Note : * significantly different from unity at 1% level
- not significantly different from unity at 10% level
MP = marginal productivity= b(Y/X)
Price ratio = input price/output price
s(MP) = standard deviation of MP = s_b (Y/X)
k = MP(Py/Px)

The t-test of k to unity is using $t_k = \dfrac{k - 1}{s(MP)(Py/Px)}$

Table 10. **Marginal Productivity of Labor, Tractor, and Draught Animal, And The Test of Input Use Efficiency**

Input	Geometric mean		Output elasticity	MP	s (MP)	Price ratio Px/Py	k
	Input	Output					
Rancaudik 1982/83 wet season							
Labor	534.0	3153.6	.2026	1.197	.522	.6638	1.825 ns
Tractor	2.681	3153.6	.0666	78.330	33.346	33.546	2.341 ns
Rancaudik 1982 dry season							
Labor	345.3	2452.5	.4280	3.040	.461	.7283	4.174*
Tractor	1.788	2452.5	.0416	57.059	25.667	35.773	1.595 ns
Rancaekek 1982/83 wet season							
Labor	610.9	1554.9	.0484	.123	.051	.9516	.1295*
Animal	1.686	1554.9	.1045	98.276	3.901	4.208	23.363 *
Tractor	6.016	1554.9	.1066	26.369	1.430	9.312	2.901 *
Gadingsari 1979/80 wet season							
Labor	48.03	384.9	.0110	.088	.065	2.8307	.0311*
Animal	.258	384.9	.0352	52.610	10.783	9.4363	5.5753*
Gadingsari 1979 dry season							
Labor	50.19	415.7	.0031	.026	.073	2.8125	.0091*
Animal	.295	415.7	.0284	9.185	8.632	9.375	4.3064*

Note: * significantly different from unity at 1% level
ns not significantly different from unity at 5% level
MP = marginal productivity = b(Y/X)
Price ratio = input price/output price
s(MP) = standard deviation of MP = s_b (Y/X)
k = MP(Py/Px)

The t-test of k to unity is using $t_k = \dfrac{k-1}{s(MP)(Py/Px)}$