THE MEASUREMENT OF TOTAL FACTOR PRODUCTIVITY GROWTH USING PRODUCTION FRONTIER: A CASE OF IRRIGATED RICE FARMING IN WEST JAVA

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ABSTRAK

Pengukuran Produktivitas Faktor Total dengan Menggunakan Fungsi Produksi Frontier: Studi Kasus Usahatani Padi Irrigasi di Jawa Barat. Penelitian ini mencoba mengukur perubahan teknologi dan perubahan efisiensi teknis serta kontribusinya terhadap pertumbuhan produktivitas faktor total pada padi sawah irigasi di Jawa Barat, dengan menggunakan fungsi produksi frontier stokastik. Data yang digunakan ialah hasil survai pada musim hujan 1980, 1988, dan 1992. Pendugaan fungsi produksi frontier dilakukan dengan metode ***maximum likelihood estimation*** (MLE) dengan menggunakan perangkat lunak LIMDEP. Hasil penelitian menunjukkan bahwa perubahan teknologi dari tahun 1980 sampai 1988 sebesar 42,74 persen. Dalam periode yang sama, efisiensi teknis turun sebesar 2 persen. Oleh karena itu, pertumbuhan produktivitas. faktor total dari tahun 1980 sampai 1988 adalah sebesar 40,74 persen. Sebaliknya, dari tahun 1988 sampai 1992 terjadi penurunan produksi frontier sebesar 51,57 persen dan kenaikan efisiensi teknis sebesar 2,06 persen. Pada periode tersebut, pertumbuhan produktivitas faktor total adalah sebesar -49,51 persen. Kenaikan produktivitas faktor total dari tahun 1980 sampai 1988 diduga disebabkan oleh perbaikan tingkat penerapan teknologi dari awal Insus sampai Supra Insus. Setelah Supra Insus, tidak ada lagi terobosan teknologi baru, baik dari segi kultur teknis maupun varietas baru yang berpotensi hasil melebihi varietas-varietas sebelumnya. Selain stagnasi teknologi, telah banyak dijumpai adanya penurunan potensi hasil secara genetik dari varietas yang ada saat ini. Penanaman padi secara terus menerus pada lahan sawah yang sama telah dibuktikan menurunkan kualitas dan kesuburan tanah, sehingga produktivitasnya menurun. Penurunan produktivitas faktor total di daerah penelitian diduga disebabkan oleh ketiga faktor di atas. Faktor keempat yang juga diduga sebagai penyebab turunnya produktivitas ini adalah adanya serangan hama pada musim tanam 1992. Hasil penelitian ini juga menunjukkan bahwa perubahan teknologi selama periode analisis cenderung bias kearah pengurangan benih dan tenaga kerja serta peningkatan pemakaian pupuk, pestisida, dan traktor. Juga ditemukan adanya hubungan yang negatif antara peningkatan produksi frontier dengan tingkat efisiensi teknis.

INTRODUCTION

Background

Most of the rice-producing countries, mainly in Asia, now face the problem of declining rice productivity growth. Although rice production and yield continues

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to increase throughout most of Asia, recent trends indicate yield stagnation and declining factor productivity (Cassman and Pingali, 1993).

Pingali *et al* (1990) stated that the post-Green Revolution phase of the irrigated rice-producing environments in Asia can be characterized by (a) well-established use of modern varieties and a decreasing growth rate in farm yields; (b) high land use intensity and input use (especially fertilizer); (c) low input use efficiency. With these factors, one should anticipate productivity declines in the future.

In Indonesia, rice production pattern during the 23 year period, from the beginning of Pelita I (1969) until the third year of Pelita V (1991), showed an average growth rate of 4.3% per year. The growth trend, however, exhibited a decreasing pattern, particularly after Pelita III. The annual growth decreased significantly from 6.6% per year during Pelita III to 3.4% and 2.4% per year during Pelita IV and the first three years of Pelita V, respectively. The success in obtaining self sufficiency in the first year of Pelita IV (1984) seems to be unsustainable. Although there was a substantial production growth of 7.34% in 1989, the average growth from 1985 to 1991 (after obtaining rice self-sufficiency) was generally about 2.3% per year. Even during 1990 and 1991, rice production only grew 1.01% and -1.09% per year, respectively, although the area planted to HYVs has increased.

Some constraints must have contributed to this slow production growth. First, some accumulative impacts of natural and biological stress, such as the drought in 1986 and 1991, and the occurrence of brown planthopper (BPH) in 1986/87 and bacterial red stripe (BRS) and stem borer during the 1989/90 wet season, have caused a sharp decline in production. The 1991 drought affected 843,917 ha, and 190,071 ha of which were totally destroyed. The white stem borer outbreak during the 1989/90 wet season damaged about 65,000 ha of lowland rice in the northern coastal areas of West Java. About 23,000 ha were totally destroyed (CRIFC, 1991, 1992). Second, the rapid growth of the industrial and service sectors caused 30,000 ha of productive land in Java to shrink because of the demand for such land for factories, highways, housing, and other public facilities (CRIFC, 1992). Third, the increase in production cost as a result of the increase in labor wages as well as fertilizer and pesticide prices caused production to slow down. The real wages of unskilled labor have increased substantially during the 1980s. Collier (1988), as cited by Darwanto (1993), reported that the real wage was increased from 0.6-1.2 kg equivalent rough rice in 1981 to 0.8-2.0 kg rough rice in 1987, or it increased by 7.6% per year. Since 1988, fertilizer subsidy has gradually been reduced, and pesticide subsidy is being phased out. The price of urea increased from Rp 125/kg in 1986 and 1987 to Rp 135 in 1988; Rp 165 in 1989; Rp 185 in 1990; Rp 210 in 1990; Rp 220 in 1991; and to Rp 240 in 1992 to reduce the subsidy burden (Hasan and Darmawan, 1994). On the other hand, most of Indonesia's success in expanding rice production is attributed to a combination of input subsidy and output price policies that improved the profitability of rice cultivation since 1968 (Pearson *et al* 1991). Timmer (1985) as cited by Pearson (1991) estimated that the improved incentives to farmers created by the fertilizer subsidy and stable rice prices contributed to about one-half of the growth in rice production from 1968 to 1984. This kind of policy becomes more difficult to maintain.

Fourth, serious government's efforts to obtain self-sufficiency in soybean and maize will divert attention and resources away from rice production.

It is presumed that another factor is the inability of farmers to use their resources efficiently. Sumodiningrat (1989), Kasryno (1985), Adnyana *et al* (1990) and Darwanto (1993) pointed out that a relatively high proportion of rice farmers in Java are using more fertilizer than what is recommended, resulting in a negative effect on yield.

On the demand side, the recent population growth of 1.9% per year, coupled with an increase in per capita consumption of rice, requires a continuous increase in rice production. The per capita consumption is increasing in line with the increase in per capita income by 5.1% per year. Rice is still considered a normal good, as shown by its income elasticity of demand of 0.4 (Jatileksono, 1986). Even Indonesian consumers associate rice with social status. Rice is considered to have a higher social status than that of the other sources of carbohydrate, except wheat (Affandi, 1985). Therefore, the sustainability of rice self-sufficiency remains in question.

To maintain rice self sufficiency, the government introduced the new package of technoloby namely Supra Insus in 1987 as an improvement of Insus that introduced in 1979.

This study aimed to examine the impact of the technological change on the TFP growth.

Objectives

Based on the above mentioned problems, the objectives of this study are as follows:

1. To measure the rate of technological change and the rate of change in technical efficiency and their respective contribution to TFP growth from 1980 to 1988 and from 1988 to 1992.
2. To describe the nature of technological change.
3. To offer some appropriate policy implications associated with the government effort to improve the growth rate of TFP.

RESEARCH METHODOLOGY

Theoretical Framework

Theoretically, productivity is defined as the rate of output produced per unit of input used in a production process. The total factor productivity (TFP), on the other hand, is the ratio of aggregate outputs to the aggregate inputs. Otsuka (1988) and Antle and Capalbo (1988) termed the rate of growth of TFP as a proportionate rate of output growth that cannot be explained by the growth of inputs due to contribution of a technological progress.

Conventionally, the change in TFP is measured as a change of productivity over time or the derivative of the logarithmic of output with respect to time variable. Defining Y as an aggregate output index and X as an aggregate input index, TFP = Y/X, and the growth rate of TFP is d ln (TFP)/dt = d ln Y/dt - d ln X/dt (Antle and Capalbo, 1988; Antle and McGuckin, 1993).

Antle and Capalbo (1988) defined technological change as changes in a production process that come about from the application of scientific knowledge. A technological change is said to be neutral if the progress of the technology is in such a way that neither saves labor (uses capital) nor uses labor (saves capital). In this case, there is only a parallel shift in production function shown by the change in its intercept without a change in the coefficient of any input. On the other hand, if changes in technology result in changes in the marginal rate of substitution, then technological change is non-neutral or bias. The bias can be either labor-saving (capital-using) or labor-using (capital-saving).

As a component of TFP growth, technological change should be measured at its best practice production frontier. Only under the frontier can true technological change be measured. Similarly, technical efficiency can be measured if there is a frontier function.

The theoretical definition of frontier production function pioneered by Farrell (1957) is that it is the maximum possible amount of output obtained from the given input bundles at a certain level of technology. The frontier cost function is defined as the minimum possible level of cost at which a certain level of output is produced, given input prices. The frontier profit function, on the other hand, is a maximum profit that can be attained given output and input prices.

By definition, unlike an ordinary least-square production function, the frontier production function does not allow any negative gap between yield on frontier and actual yield of the observation, (Y_{fr} - Y_{ob}), at the same level of inputs. This means that no point lies above the frontier. The amount by which a firm lies below its production frontier or profit frontier and the amount by which it lies above its cost frontier can be regarded as measures of inefficiency. The measurement of inefficiency has been the main motivation for the study of frontier function. This frontier function by Farrell was considered as an effort to bridge the gap between theory and empirical work (Aigner *et al* 1977, Forsund *et al* 1980).

There are two types of production frontier -- the deterministic and the stochastic frontier. This study is using stochastic production frontier. The estimate of technical inefficiency is based on the formula suggested by Jondrow *et al* (1982).

The Measurement of TFP Growth

In general, there are two approaches to the measurement of TFP growth i.e. "growth accounting (index number) approach" and the "econometric approach." This study is using the econometric approach. By using the econometric approach, the TFP growth can be derived from the econometrically estimated parameters of the production function.

This approach also enable us to derive the production elasticities with respect to each input from the estimated parameters. Another advantage is that one can use the frontier function from which the technical efficiency of the production process can be obtained.

In the conventional approach to the measurement of TFP growth most economist adopt that, under constant returns to scale, the TFP growth is equal to **primal rate of technological change**. This conventional approach only captures TFP growth under constant technical efficiency or the technically efficient firms (see Swastika, 1995).

Nizhimizu and Page (1982) pointed out an important weakness in the conventional approach -- it does not permit distinction between technological change and gains in technical efficiency, with which known technology is applied to production process. According to them, most productivity literature used the concept of TFP growth synonymously with technological change, and ignored the contribution of technical efficiency gains. In studying the productivity performance of developing economies, the distinction between technological change and technical efficiency is particularly relevant. There is accumulating evidence that the productivity gain due to technological mastery is substantial in developing economies, and may outweigh the gains from technological progress. Therefore, Nishimizu and Page (1982) introduced a model to measure TFP growth which is consisting of two components -- the shift in production frontier due to technological change and the gains in technical efficiency.

In graphical presentation, Nishimizu and Page (1982) illustrated the TFP change which consists of technological change and technical efficiency gains net of scale effect (Figure 1). From Figure 1, let A be the observed level of productivity in period 1 and B the observed level of productivity in period 2. Since $F^1(X)$ and $F^2(X)$ represent the production frontiers in period 1 and period 2, respectively, then $AA^1 = DC = e_1$ and $BB^1 = DE = e_2$, representing the technical inefficiency in period

1 and period 2. The technological progress is the change in frontier from $F^1(X)$ to $F^2(X)$, represented by B^1C. The change in TFP is B^1C plus gains from improvement in technical efficiency represented by $EC = e_1 - e_2$.

Hence, the change in TFP is represented by B^1E which is B^1C plus CE. Therefore, if there is an improvement in technical efficiency, the TFP growth will be greater than technological change. Meanwhile, deterioration in technical efficiency results in a TFP growth less than technological change.

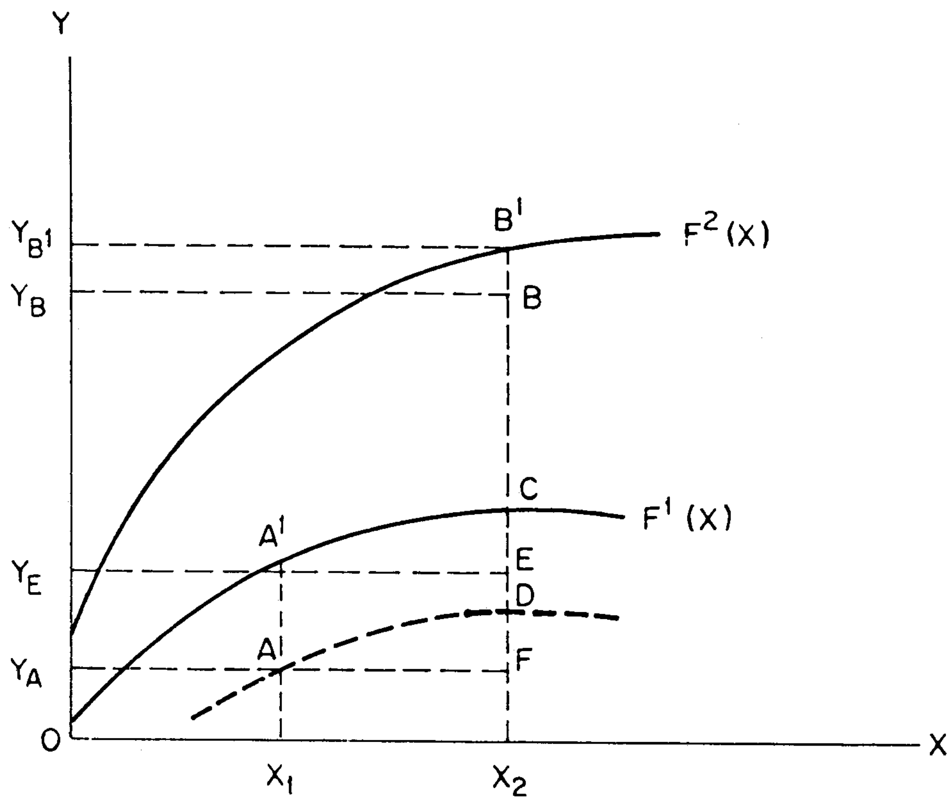

Figure 1. The total factor productivity growth.

Note:
$e_1 = AA^1 = DC$
$e_2 = BB^1 = DE$
$e_1 - e^2 = DC - DE = CE$ = gain in Tech. Eff.
$TFP = EC + CB^1 = B^1E$

This study focuses the analysis on the application of the framework suggested by Nishimizu and Page (1982) by which TFP growth is composed of two main components, namely technological change and change in technical efficiency. The difference of this study with that of Nishimizu and Page is the type of frontier production function used. This study is using a stochastic translog production frontier instead of a deterministic frontier. The use of stochastic frontier enables us to measure the residual that is purely due to technical inefficiency as suggested by Jondrow *et al* 1982. Another difference is the technology variable. This study using time dummy, while Nishimizu and Page (1982) used continuous time variable.

The true technological change is measured as $\partial \ln Q/\partial t$, while the gains in technical efficiency is measured as a change in average technical efficiency over time. The nature of technological change are observed from the intercept (indicating neutral technological change) and the over-time change in production elasticity with respect to each input (indicating bias technological change).

Selection of the Study Area

The study took place in two districts, Subang and Indramayu, West Java. Two subdistricts were chosen in each disdrict and one village for each subdistrict was selected. Therefore, four villages were selected in this study. The four villages were Tambakdahan in Binong subdistrict, Bojong Tengah in Compreng subdistrict, Anjatan in Anjatan subdistrict, and Sukadana in Bangodua subdistrict. The first two villages are in Subang, while the remaining two villages are in Indramayu.

This study uses data collected by IRRI in collaboration with CASER and CRIFC, Indonesia, in three periods -- 1980, 1988, and 1992 wet seasons. The data in 1980 represents the level of technology during early Insus, while the data in 1988 and 1992 represent the level of technology during Supra Insus and Post Supra Insus, respectively.

A total of 70 farmers were selected in each period. For the purposes of analysis, cross-section data in three time periods are combined. Thus, the data are pooled into one set, involving time dummy as a proxy for different levels of technology.

The data used in this study include size of operation, seed, fertilizer, pesticide, labor, and tractor use, yield, fertilizer price, pesticide price, rice price, and some other related information.

The Empirical Model

The model used in this study is the stochastic translog production frontier as expressed in equation (1).

$$\ln Q = \alpha_o + \sum_{i=1}^{n} \alpha_i \ln X_i + 0.5 \sum_{i=1}^{n}\sum_{J=1}^{n} \alpha_{ij} \ln X_i \ln X_i$$

$$+ \beta_1 T_1 + \beta_2 T_2 + \sum_{i=1}^{n} \beta_{1i} T_1 \ln X_i$$

$$+ \sum_{i=1}^{n} \beta_{2i} T_{2i} \ln X_i + e \qquad 1)$$

where Q is an output level, X_i is a vector of inputs, consists of seed, fertilizer, pesticide, labor, and tractor use. T_1 is time dummy as a proxy for technology in 1988, taking the value of one for 1988 and zero, otherwise. T_2 is the second time dummy as a proxy for technology in 1992, taking the value of one for 1992 and zero, otherwise. The error terms e assumed to be consist of two components, random shock (v) and inefficiency (u).

Since levels of technology are represented by time dummies, then the measurement of technological change is done by using the prosedure of measuring the effect of the dummy on the production function (Halvorsen and Palmqvist, 1980).

The technological change is obtained as :

$$c \equiv \partial \ln Q / \partial T \qquad (2)$$

and

$$TC = \exp^{(c)} - 1 \qquad (3)$$

where: c is of the partial derivative identity of the production function with respect to time dummy, while TC is the effect of time dummy on the productivity, or the level of technological change.

The change in technical efficiency is obtained from the difference between average u_t and u_{t-k} for k years time lag. After obtaining the rate of technological change and the change in average technical efficiency, the TFP growth is simply the sum of these two components.

RESULTS AND DISCUSSION

The Estimation of Stochastic Production Frontier

The stochastic translog production frontier of equation (1) was estimated by using the maximum likelihood estimation (MLE), under the stochastic frontier procedure and the assumption of half normal distribution of u (the error term due to technical inefficiency) provided by LIMDEP. This estimation gives two types of error terms -- (i) normally distributed random error and (ii) half normal error that can be attributed to the inefficiency of each farm (Jondrow *et al* 1982). The coefficients of the estimated stochastic translog production frontier are presented in Table 1. As shown in the Table 1, many variables are statistically not significant. This is a common problem of using translog model, where by interacting all variables will creates some multicolinierity among interacted variables. On the other hand, the frontier itself reduces number of significannt variables, compared to the OLS estimation. This is reasonable, since the frontier is the upper bound of the function. However, since the main objective of this model is to measure the effect of dummy variables (Technology represented by T1 and T2), this model is acceptable.

The general figure shown by Table 1 indicates an upward shift of production frontier from 1980 to 1988, and the reverse occurred from 1988 to 1992. These shifts can be roughly observed from the coefficients of variables T1, T2, and their interactions with the other variables. It also showed that the gaps between actual output and its frontier was mainly due to technical efficiency rather than random shock. This was shown by the value of λ which is higher than one.

The Elasticities of Production with respect to Input Use

The elasticities of production with respect to input use are presented in Table 2. The elasticity of production with respect to seed showed a decreasing trend. Even in 1992, production elasticity of seed was negative. A 10 percent reduction in seed use (indeed with a good quality), will result in an increase in yield by 1.35 percent.

In quantity terms, using 1992 as a current input and output level, then a decrease by 2.25 kg of seed will increase the yield by about 70.9 kg of paddy. This result implies that the use of seed was already beyond the optimal level. The lower yield resulted from a higher quantity of seed may be due to greater competition in nutrient uptake by the higher population and more tillers per hill. As a result, more tillers become non-productive, while the non-productive tillers compete with the productive tillers for nutrients. Thus, the productive tillers have lower nutrient uptake, and hence, lower yield. A decline in production elasticity for seed also indicates a seed-saving technological change under the period of concerned.

The elasticity of production with respect to fertilizer showed an increasing trend. Using 1992 as current output and input use, this result implies that an additional 1.76 kg of fertilizer will results in an additional yield of 8.52 kg/ha. In real value terms, an additional fertilizer cost of Rp 313 will results in an additional return of Rp 596/ha, holding other input constant. This result indicates that there was an incentive for farmers to use more fertilizer up to a certain level.

The elasticity of production with respect to pesticide showed an increasing trend from 1980 to 1992 (Table 2). These results imply that the problem of pests in 1992 became more important than in 1988 and 1980. The yield losses can be prevented by applying pesticide greater in a situation when pest is a serious problem than in a normal situation. The negative elasticity of production with respect to pesticide in 1980 means that the additional use of pesticide was useless because it reduced yield. This indicated that there was no problem of pest infestation in 1980. In 1988 and 1992, pest problem became more important, as shown by the positive elasticity of production with respect to pesticide use. In 1988, 1 percent additional cost of pesticide could prevent 0.03 percent of yield from loss. In value terms, an additional pesticide cost of Rp 130 per hectare could prevent Rp 166 of revenue from loss per hectare. In 1992, additional use of pesticide by one percent could prevent 0.13 percent of yield from losses. In terms of real value, an additional pesticide cost of Rp 208 could prevent revenue from losses by Rp 475/ha. Hence, there was an incentive for farmers to use more pesticide, regardless of adverse effect of pesticide use on human health and environment. This incentive has possibly increased pesticide use. The increasing trend of production elasticity with respect to pesticide indicates a pesticide-using technological change from 1980 to 1992.

The elasticity of production with respect to labor decreased from 0.1223 in 1980 to 0.0672 in 1988 and -0.1318 in 1992. These declines imply that the relative importance of labor input was decreasing as the use of herbicide for weed control and tractor for land preparation became more important. Considering the trend of production elasticity with respect to labor, the technological change was biased toward labor-saving.

The elasticity of production with respect to tractor showed the same trend as that of pesticide. This also implies the tractor-using technological change.

Table 1. Parameter Estimates of the Stochastic Translog Production Frontier of Rice Farming in West Java, Wet Seasons 1980-92.

Variable	OLS		MLE FRONTIER	
	Coefficient	Standard Error	Coefficient	Standard Error
Constant	3.7495	6.1370	4.4166	7.9550
LSEED	2.3354	1.5870	1.9487	1.8160
LFERT	2.5687	1.4610 *	2.5184	1.7380
LPEST	-0.4510	0.5741	-0.6309	0.7321
LLABOR	-1.0448	0.9027	-1.0883	1.0710
LTRACT	0.6492	0.3279 **	0.6672	0.4027 *
LSEED2	-0.3655	0.2995	-0.4571	0.3043
LFERT2	-0.2112	0.2100	-0.1823	0.2356
LPEST2	-0.0272	0.0193	-0.0279	0.0559
LLABOR2	0.1582	0.1349	0.1531	0.1669
LTRACT2	-0.0152	0.0137	-0.0134	0.0204
LSEFERT	-0.2163	0.2083	-0.1744	0.2533
LSEPEST	0.1146	0.1031	0.1727	0.1176
LSELAB	-0.2663	0.1691	-0.2648	0.1972
LSETRACT	-0.0823	0.0450 *	-0.0878	0.0667
LFERPEST	-0.0854	0.0731	-0.1008	0.0890
LFERLAB	0.0129	0.1260	0.0021	0.1409
LFERTRAC	-0.0322	0.0327	-0.0308	0.0377
LPESLAB	0.1418	0.0569 **	0.1550	0.0693 **
LPESTRAC	-0.0233	0.0220	-0.0207	0.0377
LLABTRAC	-0.0106	0.0221	-0.0164	0.0323
LSEEDT1	0.0296	0.2243	-0.0433	0.2882
LFERTT1	0.0524	0.1624	0.0087	0.1861
LPESTT1	0.2014	0.0792 **	0.2446	0.0959 **
LLABORT1	-0.0276	0.1417	-0.0551	0.1539
LTRACTT1	0.0348	0.0348	0.0415	0.0801
LSEEDT2	-0.0477	0.3026	-0.2004	0.3985
LFERTT2	0.0760	0.1942	0.0355	0.2291
LPESTT2	0.3095	0.0964 ***	0.3418	0.1444 **
LLABORT2	-0.2355	0.1985	-0.2541	0.2267
LTRACTT2	0.3767	0.0823 ***	0.3417	0.1210 ***
T1	-1.9870	1.3760	-2.0311	1.7050
T2	-2.4629	1.7440	-1.8652	2.0610
λ	-	-	1.9161	0.5899 ***
$\sum$	-	-	0.2176	0.0223 ***
R2	0.5000	-	-	-
Log-likelihood	-	-	98.4579	-

* significant at 10% level.
** significant at 5% level.
*** significant at 1% level.

Table 2. The Elasticities of Production with Respect to Each Input of Rice Farming in West Java, 1980-92.

Input	1980	1988	1992
Seed	0.0654	0.0222	-0.1349
Fertilizer	0.1266	0.1354	0.1622
Pesticide	-0.2111	0.0335	0.1307
Labor	0.1223	0.0672	-0.1318
Tractor	-0.0289	0.0125	0.3127
Total elasticity	0.0743	0.2708	0.3389

Technological Change

Based on the estimation of stochastic translog production frontier, the presence of technological change can be identified by evaluating the coefficients of T1 and T2 and their interactions with the other variables. The non-significance of the coefficients of T1 and T2 indicate that technological change did not significantly alter the intercept of the frontier. It only changed the slopes of the frontier. Thus, technological change from 1980 to 1988 and from 1988 to 1992 were of the non-neutral types.

Further analysis of the magnitudes of technological change is computed by applying equation (3) to the estimated production frontier. The technological change from 1980 to 1988 was 42.74 percent. This technological change was of the non-neutral type, since the coefficient of T1 was not significantly different from zero, while the coefficient of LPESTT1 was significantly different from zero at 5 percent level. The coefficient of LTRACTT1 was not significant, however, its positive sign together with the positive coefficient of LPESTT1 indicate that technological change was biased toward pesticide and tractor-using.

Using the same method of analysis, there was a downward shift of production frontier from 1980 to 1992 by 8.83 percent. The technological change from 1988 to 1992 therefore was -51.57 percent. The type of technological change was also non-neutral, as shown by the coefficients of LPESTT2, and LTRACTT2 which are significantly different from zero. The positive coefficients of both LPESTT2 and LTRACTT2 indicate that technological change was biased toward pesticide and tractor-using.

The labor-saving technological change was likely present, as indicated by the negative coefficients of LLABORT1 and LLABORT2, although they are not significant because of high standard deviations that are probably due to a problem of multi-collinearity. However, the decreasing elasticity of production with respect to labor indicates a labor-saving technological change.

Technical Efficiency

The technical inefficiency is computed by applying the formula suggested by Jondrow *et al* 1982 to the estimated production frontier, under the assumption of half normal distribution of u_i, the error terms being attributed to technical inefficiency. The technical efficiency is obtained by subtracting the farm level technical inefficiency from one. The distribution of technical efficiency is presented in Table 3.

The level of technical efficiencies varied and ranged at 49.4-96.9 percent in 1980, 49.4-96.5 percent in 1988, and 40.6-95.1 percent in 1992. The average technical efficiency were 85.2, 83.6, and 85.3 percent in1980,1988,and 1992, respectively. There was likely a negative relationship between level of technical efficiency and technological change. A high rate of technological change from 1980 to 1988 was followed by a degradation in technical efficiency. In contrast, a downward shift in production frontier from 1988 to 1992 accompanied by an increase in technical efficiency.

Table 3. The Distribution of Technical Efficiency of Rice Farming in West Java, 1980-92.

Range of Technical Efficiency	Percentage of Sample		
	1980	1988	1992
< 0.80	24.3	32.9	24.3
0.81 - 0.90	45.7	32.9	37.1
> 0.90	30.0	34.2	38.6

Another important result is that there was a widening range of technical efficiency from 1980 to 1992. These ranges indicated that there was an increase in the unexploited yield by farmers. This unexploited yield, if can be reduced, it would be a potential source of productivity growth. This result confirmed the finding of Pingali *et al* (1990). They found a widening yield gap among farmers, especially between the one-third top and the remaining two-thirds in Laguna and Nueva Ecija, The Philippines. Furthermore, they argued that if the rice technology continues to remain stagnant, then the future gains in productivity would have to come from bridging the gap between farmers' yield.

The Total Factor Productivity Growth

The TFP growth using production frontier is measured as the sum of technological change and the gain from the change in technical efficiency. As mentioned earlier, the level of technological change from 1980 to 1988 was 42.74 percent. During the same period, there was a decline in technical efficiency by 2.00 percent. The TFP growth, therefore, was 40.74 percent from 1980 to 1988, at a rate of 4.34 percent per year (Table 4).

Table 4. Technological Change, Technical Efficiency Gains and TFP Growth of Rice Farming in West Java, 1980-92

Components of TFP	1980 - 88	1988 - 92	1980 - 92
Technological change	42.74	-51.57	-8.83
Technical efficiency gains	-2.00	2.06	0.06
TFP growth	40.74	-49.51	-8.77

In contrast, from 1980 to 1992 a negative TFP growth occurred due to a downward shift of the production frontier. As shown in Table 4, the level of technological change was -8.83 percent followed by the gain in technical efficiency of 0.06 percent. Thus, the TFP growth was -8.77 percent. Therefore, the TFP growth from 1988 to 1992 was -49.51 percent.

A relatively high growth of TFP from 1980 to 1988 have solely contributed by the high rate of technological change. Such a change in technology occurred through improvement of intensification program from early Insus introduced in 1979 to Supra Insus introduced in 1987.

The components of technology being improved were: land preparation, crop management and pest control using pesticide, along with the more intensive use of HYVs resistant to BPH as the main component. The introduction of the second-generation Indonesian modern varieties (IMV2) in the early 1980s and followed by that of IR64 in 1986/87 has contributed to a significant increase in rice yield.

The social innovation was strengthened. Farmers worked in groups, and cooperation among farmers groups was enhanced. These intensification programs have successfully lifted the production frontier upward, resulting in a high positive growth of TFP.

After 1988, TFP sharply declined, indicated by a substantial downward shift of production frontier. Thus, the technological change has become the primary source of productivity growth, and it outweighs the gains in technical efficiency in both periods.

A sharp decline in production frontier raising another question -- what factors caused the substantial downward shift in production frontier from 1988 to 1992? The lack of technological breakthrough after 1988 did not necessarily cause a sharp decline in production frontier. Rather, stagnation is a more reasonable explanation. There must be some physical, biological, and environmental stresses that caused such a decline.

The biological stress, such as pest infestation, apparently being a dominant factor determining the decline in productivity. In the 1992 wet season, about 94 percent of farmers faced the problem of pest infestation. White stem borer was likely the most serious problem starting from the 1989/90 wet season.

A decline in the yield potential of existing varieties has been reported in some countries, both in the experiment station and farmers field (Flinn *et al* 1982; Flinn and De Datta, 1984; and Pingali *et al* 1990). The same phenomenon probably also happened in the study area. This should be proven by long-term experiments (both in experiment station as well as in the farms) using the same existing varieties. Unfortunately, this kind of study has not been done in the surrounding study area.

Another possible factor causing the decline in productivity is environmental degradation. This degradation could be due to continuous rice cropping as reported in Maros (Sulawesi), where rice has been continously grown for 11 years. In the study area, rice has been grown at least twice a year, continuously for more than 20 years, since the big dam, Jatiluhur, was started to operate in 1969.

The decline in productivity on the area where intensive and continuous rice cropping is practiced was also found by Cassman and Pingali (1993). They reported that rice yield in Central Luzon and Laguna (The Philippine) in 1990 was 0.5 t/ha lower than that in 1980.

Singh (1994) pointed out that indiscriminate use of fertilizer, less use of organic manures, and non-recycling of farm wastes and heavy mining of soil nutrients by growing rice - wheat continuously for decades in the same field have resulted in nutrient imbalance in the soil.

The contribution of technical efficiency gains was relatively low, even from 1980 to 1988 it was negative. Although gains in technical efficiency was relatively low in the past periods, an increase in technical efficiency could become an important source of productivity growth in the situation where the technology is stagnant or deteriorating. As presented in Table 1, the value of λ (lambda) is greater than one. This means that the gap between the frontier and the actual yield was mainly due to variation in technical inefficiency rather than to random shock.

CONCLUSIONS AND POLICY IMPLICATIONS

Conclusions

The application of production frontier showed that the high rate of TFP growth from 1980 to 1988 has been primarily due to technological progress from the early Insus in 1980 to Supra Insus in 1988.

A sharp decline in TFP from 1988 to 1992 has been due to pest infestation that took place in the wet season 1992. Another factors that possibly caused this decline was either a decline in genetic yield potential of the existing varieties, or to an environmental degradation as a result of continuous intensive rice cropping, or due to a combination of the two.

The contribution of gains in technical eficiency in both periods was quite low. This was mainly because of no substantial change in technical efficiency was taking place. However, average technical inefficiency in the study area was about 15 percent. If 50 percent of this can be eliminated, it will contribute about 8.8 percent in irrigated rice production. Hence, it is also a significant source of productivity growth.

This study also revealed that technological change has been biased toward fertilizer, pesticide and tractor-using and seed and labor-saving. This was primarily due to improvement in seed quality and scarcity of labor as reflected by the increasing trend of real wage.

Policy Implications

Given the very important role of technological change on TFP growth and the relatively low gain in technical efficiency, there are some scenarios of policy strategy can be pursued. The first, a long-term strategy, is the development of new varieties that have higher yield potential than existing varieties. This is a necessary prerequisite if the government of Indonesia aims to maintain an annual growth of at least 2.5 percent of rice production to maintain self sufficiency. Rice breeding research should be strongly directed to HYVs without neglecting resistance to some pests. The process of producing such varieties, however, requires continuous research and is therefore costly. The use of biotechnology in plant breeding offers a good prospect in producing HYVs resistant to some insect pests.

Second, a short-term strategy, the implementation of integrated pest management (IPM) should be enhanced. The use of pesticides should be restricted only if other methods are not effective. Pesticides may be excluded from the farm credit package to avoid improper use of pesticides that may possibly cause resurgence and development of insect's resistance to some pesticides.

Third, also a short-term strategy, is to continue rice price support in combination with reduction in fertilizer subsidy. Seed subsidy may be maintained since it is the most important input, especially the HYVs. This is to encourage farmers to use better quality seed with high yield potential. Swastika (1995) reported that seed is price elastic. The withdrawal of seed subsidy may reduces the use of certified seed and increases the use of own produced seed which may causes a decline in rice production.

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