Do Macroeconomic Shocks Impact the Economic Efficiency of Small Farmers? The Case of Wetland Rice Farmers in Indonesia[1]

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Summary

The economic efficiency of Indonesian rice farmers was lower and more variable during than before the macroeconomic crisis. Specifically, larger declines in technical efficiency were not offset by smaller improvements in allocative efficiency. Farm ownership, larger farm size, and higher education were associated with higher levels of efficiency.

Keywords: technical and allocative efficiency, Indonesia, agriculture, rice

Introduction

The introduction of "seed-embodied" technologies exploded during the Green Revolution. This was coupled with the increasingly intensive use of purchased farm factors, such as fertilizer, pesticides, and irrigation water, often required to fully exploit the potential of new technologies. Much of the phenomenal growth in crop production during this period has been attributed to the continued outward shifts in the production frontier driven by these new technologies as well as the attendant increases in the use of purchased factors. The importance of these growth engines in agricultural development has spurred interest in studies focusing on whether farmers are producing at the frontier of their production function and whether their production is organized (i.e., combining factors) to minimize cost. Both Battese 1992 and Bravo-Ureta and Pinheiro 1993 surveyed empirical applications of frontier production functions and technical efficiency in developing countries. Thiam, Bravo-Ureta, and Rivas (2001) analyzed results from 32 studies on technical efficiency in developing-country agriculture to understand the factors influencing differences in their estimates.

There is strong criticism that the intensive use of purchased (and mostly imported) inputs makes small farmers more vulnerable to economic shocks. Those who disagree claim that small farmers are somehow insulated from these shocks because of their lack of market orientation. Available literature does not provide abundant evidence on the impact of macroeconomic shocks on the efficiency of small farmers. The case of rice farmers in Indonesia provides a unique opportunity to explore this question. The Asian economic meltdown in 1997 was severe. In Indonesia, the rupiah depreciated by 244 percent in 1998, inflation skyrocketed to 75 percent, and real per capita income dropped from $1,000 in 1996 to $205.

However, Indonesia's poultry sector suffered a serious blow following the country's financial crisis of 1997 (when the rupiah depreciated by 244 percent in 1998, inflation skyrocketed to 75 percent, and real per capita income dropped from $1,000 in 1996 to $205). Production in 1998 was less than half of the 605 thousand metric ton pre-crisis level in 1996.

The general objective of this study is to examine the efficiency of wetland rice farms and the implications for Indonesia's competitive advantage and likely trade patterns. Specifically, we aim to

a. provide estimates of multiple-factor and single-factor technical, allocative, and productive efficiency measures for leading rice producing provinces of Indonesia;
b. examine the trend of efficiency measures over time and analyze the impact of a macroeconomic shock on the efficiency of farms; and
c. analyze likely causal factors explaining the differences in efficiency measures across farms.

Model

This section gives a brief survey of the efficiency literature. Farrell (1957) provided the impetus for developing the literature on empirical estimation of economic efficiency. His work led to a better understanding of the concept of economic efficiency and the subsequent development and application of several measures of economic efficiency. For example, from a single average measure of efficiency, now efficiency measures applied at the level of individual firms can be computed. From multiple-factor efficiency measures, now single-factor efficiency can be derived. Various approaches to measurement allow decomposition of overall productive efficiency measures into their technical and allocative efficiency components. Measures of efficiency can be derived based on the error term, or based on the structural equation estimated, either production or cost functions. Measures based on cost functions lend easily to their economic interpretation and have very strong intuitive appeal.

Early studies focused primarily on technical efficiency using a deterministic production function with parameters computed using mathematical programming techniques. However, with inadequate characterization of the properties of the assumed error term, this approach has an inherent limitation on the statistical inference on the parameters and resulting efficiency estimates. Aigner, Lovell, and Schmidt (1977) and Meeusen and van den Broeck (1977) independently developed the stochastic frontier production function to overcome this deficiency. Their stochastic production function model specified a composed error structure, that is,

(1) $$y_i = g(x_i, \beta) + \varepsilon_i$$

where i is an index of observation from 1 to N, y is the output, x is a vector of factors, β is a conformable vector of parameters, and ε is the error term that is composed of two elements. That is,

(2) $$\varepsilon_i = \nu_i - \mu_i$$

where ν is the symmetric disturbance assumed to be i.i.d. $N(0, \sigma_\nu^2)$ giving the stochastic structure of the frontier. The second component is a one-sided error term that is independent of ν and is distributed $|N(0, \sigma_\mu^2)|$, allowing actual production to fall below the frontier but without attributing all shortfalls in output from the frontier as inefficiency.

Earlier applications of the Aigner, Lovell, and Schmidt model were only able to estimate an average measure of technical efficiency, that is,

(3) $$\hat{\varepsilon}_i = \sigma_\mu \sqrt{2/\pi}\,.$$

Jondrow et al. (1982) advanced the Aigner, Lovell, and Schmidt procedure, developing a way of decomposing the sources of variability in the production function and allowing estimation of technical efficiency for each observation. Jondrow et al. exploited the estimated composed error ε_i to signal any information about μ_i. They used the conditional mean as a point estimator of μ, that is,

(4) $$E(\mu \mid \varepsilon) = \sigma_* \left[\frac{f(\varepsilon\lambda/\sigma)}{1 - F(\varepsilon\lambda/\sigma)} - \left(\frac{\varepsilon\lambda}{\sigma}\right) \right]$$

where

$$\sigma_* = {-\sigma_\mu \varepsilon}/{\sigma^2}\,, \quad \sigma^2 = \sigma_\upsilon^2 + \sigma_\mu^2\,, \text{ and } \lambda = {\sigma_\mu}/{\sigma_v}\,.$$

The Jondrow et al. procedure enabled studies to compare technical efficiency levels of different firms. Furthermore, it allowed examination of likely causal factors that may explain any structure in the differences of the estimated technical efficiency across firms.

Coincident with these investigations of technical efficiency was an increasing focus on the other element of productive efficiency—allocative efficiency. Schmidt and Lovell (1979) employed both a stochastic frontier production and cost functions to estimate technical and allocative efficiency. They incorporated possible allocative inefficiency by allowing deviation from the least-cost expansion path defined as the condition in a cost-minimization problem.

Whereas, the previously mentioned studies used the error term in deriving efficiency measures, Kopp (1981) developed efficiency measures derived from the structural production and cost functions. That is, efficiency measures were expressed as ratios of vector norms comparing actual factor combinations, a technically efficient factor mix, and a technically and allocatively efficient factor mix. Kopp combined both production and cost functions to derive both technical and allocative efficiency and he developed input-specific efficiency measures. The approach lends itself easily to an intuitive economic interpretation of the efficiency measures. Kopp and Diewert (1982) extended and simplified the economic efficiency analysis by fully exploiting the duality theory, showing that all efficiency measures can be computed from information contained only from a frontier cost function. Their approach has several advantages. First, all efficiency measures are derived from a cost function without even deriving or estimating the primal production function. The multicollinearity problem common in production function estimation is avoided. More flexible cost functions that do not have a direct primal production function equivalent can be used. And the cost of inefficiencies, if any, can be easily computed.

This paper follows the model in Kopp (1981) and Kopp and Diewert (1982). To decompose the sources of multiple-factor inefficiency, three factor combinations are derived. The first is the actual factor combination, called X^A, used to produce a given output level, say, y^*. The second factor combination, called X^E, is at the frontier of the production function using the least-cost combination of factors to produce y^* at actual prices. The cost function is of the form

(5) $$C = f(y, p_i, \delta) + \xi_i$$

where y is the output level, p_i is the price of factor i, and δ is a vector of conformable parameters. The factor mix X^E is derived from the factor demand from (5) by substituting the actual output and factor prices. That is,

(6) $$x^E = \Delta_p f(y^*, p_i, \delta).$$

The third factor combination, X^B, is at the frontier production function and has the same factor proportions as the actual factor combination X^A but is determined from the least-cost expansion path at the actual prices. The expression in equation (7) puts the factor mix X^B in the frontier production function; that is,

(7) $$x^B = \Delta_p f(y^*, p_i^B, \delta)$$

but off the least-cost expansion path since $C = f(y^*, p_i, \delta) < C = f(y^*, p_i^B, \delta)$.

Also, the factor mix X^B uses the same proportion of factors as X^A, that is,

(8) $$X^B = \lambda^B X^A.$$

Combining (7) and (8) gives a 2N system of equations with (2N+1) unknowns. To solve the system, price is first normalized by dividing all prices by the $p^B{}_n$, giving

(9) $$\hat{p}_n^B = 1 \quad and \quad \hat{p}_i^B = \frac{p_i^B}{p_n^B} \quad \forall i = 1, \ldots, n-1.$$

Also, the scaling parameter λ^B is eliminated in equation (8) by dividing each ith expression by the first i=1, giving an n-1 equation of the form

(10) $$\frac{x_i^B}{x_1^B} = \frac{x_i^A}{x_1^A} \quad \forall i = 2, \ldots, n.$$

Now, equations (7) and (10) give a (2N-1) system of equations to solve for the (2N-1) unknowns, which include the N factors in X^B and the (N-1) normalized prices.

The efficiency measures are all expressed in terms of ratios of cost, where technical efficiency (TE) is defined as

(11) $$TE = \frac{px^B}{px^A}.$$

Since by definition $X^A > X^B$ (with $0<\lambda^B<1$), then it follows that $0<TE<1$.

Allocative efficiency (AE) is defined as

(12) $$AE = \frac{px^E}{px^B}.$$

Since by definition of a cost function, $pX^E = p\Delta_p f(.) \leq pX \ \forall X$, then it follows that $0<AE<1$.

Productive efficiency (PE) is defined as

(13) $$PE = \frac{px^E}{px^A}$$

Following equations (11) and (12), $0<PE<1$.

In addition to deriving the three measures of factor productive efficiency, we derive factor-specific efficiency measures. These measures provide an indication of the efficiency of scarce resources and can be used to rank the efficiency measure of all resources.

In an N-dimensional factor vector, the factor combination used for factor-specific efficiency measures is determined as the minimum quantity of the jth factor to produce an output level given a fixed level of all factors $i \neq j$. The first step is to derive this factor combination for all factors. Similar to the multiple-factor measures of efficiency, from the estimated cost function, the factor demand is derived for the N-factors by taking the partial derivative of the cost function with respect to the factor prices. In this system of equations, we substitute the actual output and the level of each factor $i \neq j$, excluding the jth factor. This system gives N equations with (N+1) unknown, including the N factor prices and one unknown factor. Factor prices are again normalized to solve the system of equations; that is,

$$(14) \qquad x_i^S = \Delta_{p_i} f(y^*, p^S, \delta) .$$

where superscript S stands for factor-specific demand, holding all other factors constant at their actual level,

$$(15) \qquad x_i^S = K_i \quad \forall i \neq j ,$$

and prices are

$$(16) \qquad \hat{p}_n^S = 1 \quad \text{and} \quad \hat{p}_i^S = \frac{p_i^S}{p_n^S} \quad \forall i = 1,...,n-1 .$$

Equations (15) and (16) are successively solved for each jth factor until all the minimum levels of the N factors are solved, and the total cost of the solved factor combination is computed using actual prices. Since these factor combinations are not in the same proportions as the actual factor combination, the efficiency measures cannot be based on total cost. The appropriate efficiency measure is based on the factor mix that falls both in the isocost line and the actual factor proportions.

To implement this analysis, we specify and estimate a Cobb-Douglas frontier cost function:

$$(17) \qquad C = \exp(\delta_0 + \sum_{i=1}^{n} \delta_i \ln p_i + \delta_y \ln y + v - \mu) .$$

With the parameter vector δ in (17) estimated, the respective factor combinations needed to estimate the multiple factor measures of efficiency are derived using Newton's method of solving nonlinear systems of equations. Further analysis will be conducted to regress the efficiency measures with farm characteristics to explain differences in the efficiency across farms.

Empirical Results and Discussion

Data used in this analysis is taken from the survey "Cost Structure of Paddy and Secondary Food Crops" from Indonesia's statistics bureau, Badan Pusat Statistik (BPS). The BPS collects production and expenditure data at the farm level for the entire country. A cost function is estimated for wetland rice for major producing provinces. The input categories considered are land, labor, fertilizer, and seeds. Estimation of the frontier cost function in equation (17) was performed using FRONTIER 4.1 (Coelli 1996); the solution on nonlinear systems of equations by Newton's method are performed in SAS, version 8.2.

Aggregate measures of efficiency

Table 1 gives a summary of the Indonesian rice supply and utilization. Rice is the main staple in Indonesia. Per capita consumption increased significantly in the 1960s through 1980s, by 2 to 5 percent annually. The increase has slowed to around 0.3 to 0.5 percent annually in the last two decades. Average per capita consumption in the last five years is about 162 kilograms per person. The area allocated to rice production has also increased over time, with the peak level of 11.85 million hectares attained in 1998. We note that significant area, of around 5.32 percent, was brought into production during the crisis period of 1997-98, suggesting that agriculture, and rice production in particular, may have served as an employer of last resort for resources that were put out of use in other sectors. With the average national yield in 1997 falling 7 percent below the average of the previous two years, Indonesia posted the largest imports of the last three decades at 5.77 million metric tons (mmt). An additional 3.73 mmt was imported in 1998. In the most recent two years, Indonesia's rice imports represented 10 percent of domestic production. Also, Indonesia maintains a rice stock representing 12 percent of domestic use.

Table 2 shows that the islands of Java, Sumatra, and Sulawesi are the leading producers of rice in Indonesia. Java accounts for the highest share of total area planted to rice at 44 percent. This is followed by Sumatra at 15 percent and Sulawesi at 10 percent. Provinces with a large share of area planted to rice in most cases are also provinces with higher yields.

Table 3 shows that in terms of yield per hectare, Indonesia is in the middle when compared with its neighboring countries. Countries in North Asia, including China, Japan, Taiwan, and South Korea, show higher yields in the range of 4 to 5 metric tons (mt) of milled rice per hectare. On the other hand, comparable countries in Southeast Asia, including Pakistan, the Philippines, Myanmar, and Thailand, show lower yields, in the range of 1.6 to 2 mt. Indonesia had an average yield of 2.79 mt in 1996-2002.

With its limited land resources and increasing pressure from alternative nonagricultural use of arable land, Indonesia's viable options for expanding production are few. Sources of growth in the next decade will have to come largely from improvements in productivity and efficiency. Improvement in productivity refers to the outward shift of the country's production possibility frontier that allows more production at the same level of input, or less inputs used at the same level of production. Using yield as a rough proxy of productivity improvement and yield in North Asian countries as the frontier yield, Indonesia still has a lot of catching up to do.

Production efficiency estimates

Another important avenue for increasing production is the improvement in efficiency. Three measures of efficiency are used in this analysis. Technical efficiency refers to whether producers are operating at the frontier of their production possibility, while allocative efficiency refers to whether producers are combining their factors of production in a manner that minimizes cost. The product of both efficiency measures gives the productive efficiency. A frontier cost function was estimated for each year to quantify these efficiency measures based on equation (17). Table 4 gives the parameter estimates of the frontier cost function for 1996, 1998, and 1999. All parameters are significant at 1 percent and have the correct signs; that is, input price and output parameters are positive, suggesting that an increase in input prices would increase cost and an increase in output would also increase cost. As defined in equation (4), the λ parameter is the ratio of the variance of the error term μ that represents technical inefficiency and the sum of the variance of both μ and the variance of the standard random error term υ. Findings of λ values of between 0.69 to 0.79 suggest that a large proportion of any departure from the frontier cost function is explained more by the variability due to the technical inefficiency error term than by the variability due to the standard random error term.

Estimates at the province level

Tables 5a through 5c show the prices, actual input use and mix, and resulting efficiency measures for three leading rice producing provinces in Indonesia: West Java, East Java, and Central Java, and for all of Indonesia (Table 5d). As shown in these tables, prices of inputs increased dramatically during the macroeconomic crisis, with prices of traded inputs such as fertilizer increasing more than prices of nontraded inputs such as labor, at 357 to 457 percent and 94 to 150 percent, respectively. The price of land increased by 114 to 152 percent and the price of seeds increased by 194 to 229 percent.

The three leading rice producing provinces in Indonesia showed similarities as well as differences in their responses to the macroeconomic shock. Common across the three provinces was the increase in the average area planted per farm at the rate of 7 to 25 percent, most likely intended to absorb resources, especially labor, displaced from other sectors. This is consistent with the national data showing a significant increase in area planted to rice in 1997-98. However, the adjustment in the intensity (i.e., input utilization on a per area basis) of use of the other inputs differed markedly. In West Java, for example, fertilizer use per hectare declined by 6 percent, while labor use increased by 41 percent. Seed use also increased by 6 percent. In East Java, per hectare utilization of all inputs increased, with labor having the largest increase of 45 percent. In contrast, utilization of all inputs declined in the case of Central Java. Of the four inputs, the largest decrease was in labor use.

In 1996, productive efficiency of wetland rice farmers in the leading three provinces in Indonesia ranged from 81 to 88 percent. That is, the cost of the economically (i.e., both technical and allocative) efficient factor combination is 81 to 88 percent compared with the cost of the actual mix of factors. This efficiency measure represents a high technical efficiency in the range of 90 to 99 percent and an allocative efficiency in the range of 84 to 89 percent (Tables 5a through 5c). The impact of the macroeconomic shock is similar across the three provinces in terms of direction but very different in terms of magnitude, reflecting the different adjustments made in the factor combinations in these respective provinces. The macroeconomic shock reduced the productive efficiency of the three provinces by 6 to 22 percentage points. This was a combined result of a sharp reduction in technical efficiency of 7 to 25 percentage points and, partially offsetting the effect, a small improvement in the allocative efficiency of 0.34 to 4 percentage points. The sharp decline in the technical efficiency may be attributable to a number of factors. As more displaced labor was absorbed into agriculture, particularly in rice farming, either as independent farmers or as wage earners, the skill level of the labor pool likely suffered. Also, the additional land brought into production to accommodate the displaced labor was likely to be of a lower quality. The high cost of credit during the macroeconomic crisis also may have served as an effective constraint in allowing farmers to operate at the frontier of their production function. On the other hand, the small improvement in the allocative efficiency may have resulted from the high price of the inputs that induced farmers to combine their inputs at the least-cost mix.

In terms of magnitude, the sharpest decline in technical efficiency was in West Java where land area increased the least, labor use per hectare intensified significantly, and fertilizer and seed use were reduced. In contrast, the smallest decline in technical efficiency was in Central Java, where land area increased the most and the intensity of input use was reduced for all inputs. In between, but closer to West Java, was East Java, which increased area and the intensity of use of both fertilizer and labor.

In terms of specific inputs, the technical efficiency for fertilizer declined by 16 to 38 percentage points and labor declined by 7 to 49 percentage points. The sharpest decline in fertilizer technical efficiency was in East Java, by 38 percentage points, where the intensity of fertilizer use increased by 7 percentage points, while the sharpest decline in labor technical efficiency was in West Java, by 49 percentage points, where labor use intensity increased by 41 percent. The smallest decline in the technical efficiency of fertilizer (by 16 percentage points) and labor (by 6 percentage points) was in Central Java, where the intensity of use of all inputs was adjusted downward.

Factors affecting efficiency

Finally, we examined the factors explaining the differences in efficiency measures across producers. Only the 1998 and 1999 data were used because they included more detailed demographic variables of farmers. The explanatory variables used included land size; labor intensity; year; a dummy for land tenure that is equal to one if the land is owned by the farmer; age; a gender dummy equal to one for male; three education dummies representing primary school, high school, and college levels of educational attainment; and an irrigation dummy set to one if the resource was available. The results are shown in Tables 6 and 7. It is noted that owner-operator farmers with larger-size farms have higher technical and allocative efficiency measures. The age of the farmer has a positive effect on technical efficiency but is not a significant factor for allocative efficiency. Farms with male operators have a lower technical efficiency, but gender is not a significant factor for allocative efficiency. Farms with operators having at least a high school education showed higher technical efficiency compared with those with only a primary education. University-level education is not a significant factor for technical efficiency. On the other hand, allocative efficiency of farms with operators having only a primary education is not significantly different from those with high school educational attainment. Education at the university level has a positive effect on allocative efficiency. Availability of irrigation also improved the technical efficiency of farms.

Discussion

The information provided by this type of analysis can be quite useful for policymakers. Since efficiency measures can be disaggregated by type (technical and allocative efficiency), by specific factor (fertilizer and labor), and by location (provinces and individual farms), potential intervention for improvement can be specifically identified and targeted. This is important since the set of instruments for influencing technical and allocative efficiency can be quite different. For example, improvement in technical efficiency may involve technology transfer instruments while improvement in allocative efficiency may involve instruments that transfer information to improve human capital and decision making of agents. Moreover, since the efficiency measures are disaggregated on the individual farm level, there can be a geographic focus for any interventions intended to improve specific types of efficiency.

An intervention plan to improve productive efficiency in the leading rice producing provinces might entail ranking the provinces in terms of potential for improvement by using the efficiency measures such as those in Tables 5a through 5c. Based on the estimated productive efficiency, the provincial ranking for the three provinces examines would come in this order: West Java (0.66), East Java (0.72), and Central Java (0.76). The information provided by the disaggregated efficiency measures can help decisionmakers focus on the choice of instruments. For example, with lower estimated technical efficiency in West and East Java, technology-improving instruments might be targeted for those provinces; with lower estimated allocative efficiency for West and Central Java, instruments for enhancing human capital might be targeted for those provinces.

Factor-specific technical efficiency is also reported for fertilizer and labor. Over the three-year period estimated, two distinct patterns can be observed. In the case of West Java, the technical efficiency of labor declined more than did the technical efficiency of fertilizer, while it was the reverse in the case of East Java, where the technical efficiency of fertilizer dropped more than did that of labor. For Central Java, the technical efficiency of fertilizer dropped more than did labor, but by smaller magnitudes compared with the other two provinces. The differences in response of the factor-specific technical efficiency can suggest the nature of any planned intervention to improve overall efficiency. For example, if technology-transfer instruments are used for West Java, the factor-specific efficiency measures suggest that the process of technology transfer should focus more on the factor with a high share of total cost but with the low technical efficiency measure. Improvement in fertilizer use would be a particular priority for East Java and Central Java. On the other hand, West Java would benefit from improvement in the use of labor.

Another influence of the macroeconomic shock on efficiency measures was examined by comparing the variability of the efficiency measures between 1996 and 1998. For the three provinces, the average coefficient of variation of their efficiency measure is much higher in 1998 compared with 1996 by a factor of 1.87. This is additional information on the significant disruption of the macroeconomic crisis and challenge of the economic environment for achieving efficient production during this time.[2]

Summary and Conclusion

Rice is the main staple in Indonesia. The rise in per capita consumption has slowed from a high of 2 to 5 percent annually in the 1960s to 1980s to around 0.3 to 0.5 percent annually in the last two decades. Average per capita consumption in the last five years is around 162 kilograms per person. Area allocated to rice production has also increased over time, with the peak level at 11.85 million hectares attained in 1998. Area has declined to 11.5 million hectares in 2002.

With its limited land resources and increasing pressure from alternative nonagricultural use of arable land, Indonesia's viable options for expanding production are few. Sources of growth in the next decade will have to come largely from improvements in productivity and efficiency. Indonesia's rice yield record is only average compared with those of its neighboring countries; it is lower compared with the yield in North Asian countries while it is higher compared with South Asian countries.

This study quantified measures of efficiency for wetland rice production in Indonesia. To be useful for policy intervention, the efficiency measures were disaggregated into technical and allocative efficiencies. The former measures whether producers are operating at the frontier of their production possibility while the latter measures whether producers are organizing their production activity in such as way as to minimize cost. Economic efficiency measures were estimated for individual provinces. In addition, efficiency measures were estimated for specific factors.

[2] Since efficiency measures are computed for each farm, their variability can be derived at the province level.

Results are reported for the three leading rice producing provinces. Using the average of the most recent two years with available data, Central Java had the highest productive efficiency at 0.76, followed by East Java at 0.71 and West Java at 0.66. In all three provinces, allocative efficiency is higher than technical efficiency, suggesting that departures of the actual factor mix from the most efficient input combination is explained more by the distance of the actual factor mix from the frontier than by the distance of the technically efficient factor mix to the most efficient input combination. A closer examination of the factor-specific measures of technical efficiency uncovers some differences across provinces. For example, technical efficiency in the use of fertilizer is higher compared with the technical efficiency in the use of labor only in West Java. The relationship of the technical efficiency of the two inputs are reversed in the other two provinces.

The macroeconomic shock in Indonesia in 1997-98 on the economic efficiency of wetland rice farmers had a significant impact on Indonesia's rice production. Prices of traded inputs such as fertilizer increased by 357 to 457 percent, while prices of nontraded inputs such as labor increased by only 94 to 150 percent. Productive efficiency declined by 6 to 22 percentage points during the crisis, largely because of the decline in the technical efficiency by 7 to 25 percentage points. On the other hand, allocative efficiency increased by 0.34 to 4 percentage points, partially offsetting the decline in technical efficiency. West Java had the sharpest decline in technical efficiency, while Central Java had the smallest decline. Also, the technical efficiency of both fertilizer and labor declined during the crisis. Furthermore, the macroeconomic shock also made the efficiency measures more volatile.

The results estimated on the various measures of efficiency can help in designing intervention instruments to improve the efficiency of wetland rice production. The efficiency measures allow policymakers to prioritize the location (i.e., province) of intervention and choice of appropriate instruments: technology transfer to improve technical efficiency or human capital to improve choice of inputs and hence, allocative efficiency. Information on efficiency measures is valuable also because it allows targeting any intervention to particular factors of production, such as fertilizer or labor. This result is supported by the finding that larger-size irrigated farms operated by older owner-farmers with at least a high school education tended to have higher technical efficiency, and larger-size farms operated by owner-farmers with education beyond high school showed higher allocative efficiency.

Table 1. Milled rice supply and utilization 1990-2002

Year	Area	Production	Use	Export	Import	Stock
	000 ha	Thousand Metric Tons				
1990	10,282	29,042	30,121	0	192	2,951
1991	11,103	31,350	30,838	0	539	2,064
1992	11,012	31,318	31,375	472	22	3,115
1993	10,735	30,315	32,097	222	1,120	2,608
1994	11,439	32,333	32,922	0	3,081	1,724
1995	11,570	33,215	33,461	0	1,081	4,216
1996	11,137	32,084	33,911	0	839	5,051
1997	11,730	31,118	34,667	0	5,765	4,063
1998	11,850	31,853	35,033	0	3,729	6,279
1999	11,650	33,445	35,400	0	1,500	6,828
2000	11,790	32,800	35,877	0	1,500	6,373
2001	11,160	32,960	36,358	0	3,500	4,796
2002	11,500	32,832	36,790	0	3,250	4,898

Source: USDA.

Table 2. Area planted to rice, yield, and share by province in 2002

Province	Area (Ha)	Yield (mt/ha)	Share (%)
West Java	1,807,288	5.10	15.52
East Java	1,688,082	5.22	14.50
Central Java	1,658,784	5.14	14.25
Sulawesi South	834,859	4.57	7.17
Sumatera North	778,632	4.01	6.69
Sumatera South	549,211	3.33	4.72
Lampung	483,703	4.07	4.16
Banten	441,756	3.80	3.79
Kalimantan South	425,745	3.18	3.66
Sumatera West	404,710	4.49	3.48
Kalimantan West	345,049	2.82	2.96
N. Aceh Darussalam	332,301	4.19	2.85
N. Tenggara West	310,717	4.41	2.67
Indonesia	11,641,264	4.43	100.00

Source: BPS, Indonesia.

Table 3. Average yield of selected countries

Country	81-85	86-90	91-95	96-02
	Metric tons milled rice per hectare			
South Korea	4.46	4.58	4.46	4.97
Japan	3.50	4.50	4.34	4.73
China	3.49	3.82	4.08	4.39
Taiwan	3.47	3.56	4.01	3.90
Indonesia	***2.64***	***2.76***	***2.84***	***2.79***
Philippines	1.62	1.74	1.86	1.95
Pakistan	1.67	1.60	1.68	1.92
Myanmar	1.50	1.61	1.65	1.67
Thailand	1.32	1.34	1.50	1.61

Source: USDA.

Table 4. Parameter estimates of frontier cost function

	1996	1998	1999
Observations	6976	8721	7102
Intercept	-1.868	-1.411	-1.394
Output	0.733	0.661	0.666
Land price	0.254	0.262	0.257
Fertilizer price	0.160	0.104	0.127
Labor price	0.463	0.513	0.480
Seed price	0.123	0.121	0.135
σ^2	0.182	0.307	0.290
λ	0.695	0.789	0.788
LLF	-1860	-4542	-3468

Source: Estimated from survey data. *Note*: All parameter estimates are significant at 1%.

Table 5a. Average data for West Java (32)

	1996	1998	1999
Observations			
Prices			
Land price	454,786.7	1,149,791.9	1,155,420.3
Fertilizer price	903.4	5,028.1	5,311.2
Labor price	3,957.5	7,659.0	7,780.9
Seed price	738.4	2,434.3	2,487.8
Production			
Yield	5.19	4.38	4.50
Actual input mix			
Area	0.44	0.47	0.47
Fertilizer	46.60	43.95	44.75
Labor	50.44	75.96	76.42
Seed	14.13	14.91	14.83
Multiple-factor efficiency measure			
Productive	0.836	0.650	0.662
Technical	0.995	0.745	0.767
Allocative	0.840	0.874	0.863
Single-factor efficiency measure			
Fertilizer technical efficiency	0.974	0.757	0.755
Labor technical efficiency	0.989	0.503	0.515

Table 5b. Average data for East Java (35)

	1996	1998	1999
Observations			
Prices			
Land price	436,001.8	933,833.2	933,774.0
Fertilizer price	828.6	3,783.7	3,975.6
Labor price	3,229.9	6,449.7	6,564.9
Seed price	807.3	2,450.0	2,478.9
Production			
Yield	5.24	4.99	4.96
Actual input mix			
Area	0.33	0.36	0.35
Fertilizer	46.04	53.59	53.38
Labor	37.13	58.73	58.07
Seed	16.98	18.49	18.35
Multiple-factor efficiency measure			
Productive	0.878	0.716	0.716
Technical	0.988	0.792	0.789
Allocative	0.889	0.903	0.907
Single-factor efficiency measure			
Fertilizer technical efficiency	0.922	0.574	0.576
Labor technical efficiency	0.982	0.692	0.677

Table 5c. Average data for Central Java (33)

	1996	1998	1999
Observations			
Prices			
Land price	442,352.2	985,837.9	972,118.1
Fertilizer price	915.9	4,385.3	4,597.8
Labor price	3,230.4	8,060.6	8,238.8
Seed price	816.3	2,402.8	2,417.9
Production			
Yield	5.04	4.19	4.14
Actual input mix			
Area	0.28	0.35	0.35
Fertilizer	36.10	39.79	40.36
Labor	42.25	44.39	43.50
Seed	12.79	15.34	15.62
Multiple-factor efficiency measure			
Productive	0.807	0.758	0.760
Technical	0.905	0.849	0.851
Allocative	0.891	0.894	0.893
Single-factor efficiency measure			
Fertilizer technical efficiency	0.715	0.600	0.601
Labor technical efficiency	0.808	0.755	0.753

Table 5d. Average data for Indonesia

	1996	1998	1999
Observations			
Prices			
Land price	418,622.2	987,475.3	992,202.3
Fertilizer price	878.1	4,770.8	5,038.1
Labor price	3,583.2	7,744.6	7,821.9
Seed price	756.3	2,287.3	2,355.8
Production			
Yield	4.96	4.08	4.12
Actual Input Mix			
Area	0.40	0.50	0.50
Fertilizer	42.31	44.49	45.11
Labor	46.74	62.44	61.38
Seed	16.87	20.95	20.68
Multiple-factor efficiency measure			
Productive	0.825	0.688	0.694
Technical	0.944	0.771	0.783
Allocative	0.874	0.892	0.886
Single-factor efficiency measure			
Fertilizer technical efficiency	0.784	0.689	0.680
Labor technical efficiency	0.887	0.607	0.635

Table 6. Technical efficiency regression

	Coefficient	Standard Error	t-ratio
Regressors			
Intercept	0.2541	0.0483	5.260
Size	0.3929	0.0221	17.820
Labor intensity	-0.0015	0.0000	-51.110
1999 year dummy	0.0105	0.0054	1.950
Owner-operator dummy	0.0576	0.0098	5.890
Age	0.0007	0.0003	2.260
Male dummy	-0.0330	0.0124	-2.650
High school education dummy	0.0295	0.0076	3.900
University education dummy	-0.0571	0.0472	-1.210
Irrigation dummy	0.0751	0.0062	12.020

Table 7. Allocative efficiency regression

	Coefficient	Standard Error	t-ratio
Regressors			
Intercept	0.6827	0.0146	46.740
Size	0.0393	0.0067	5.880
Labor intensity	0.0002	0.0000	28.250
1999 year dummy	-0.0054	0.0016	-3.320
Owner-operator dummy	0.0397	0.0030	13.420
Age	0.0000	0.0001	-0.140
Male dummy	-0.0064	0.0038	-1.690
High school education dummy	-0.0004	0.0023	-0.180
University education dummy	0.0257	0.0143	1.800
Irrigation dummy	-0.0109	0.0019	-5.760

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