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# Impact of Environmental Factors on Profit Efficiency of Rice Production: A Study in Vietnam's Red River Delta

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***Abstract*****—**Environmental factors affect agriculture production productivity and efficiency resulted in changing of profit efficiency. This paper attempts to estimate the impacts of environmental factors to profitability of rice farmers in the Red River Delta of Vietnam. The dataset was extracted from 349 rice farmers using personal interviews. Both OLS and MLE trans-log profit functions were used in this study. Five production inputs and four environmental factors were included in these functions. The estimation of the stochastic profit frontier with a two-stage approach was used to measure profitability. The results showed that the profit efficiency was about 75% on the average and environmental factors change profit efficiency significantly beside farm specific characteristics. Plant disease, soil fertility, irrigation apply and water pollution were the four environmental factors cause profit loss in rice production. The result indicated that farmers should reduce household size, farm plots, apply row seeding technique and improve environmental factors to obtain high profit efficiency with special consideration is given for irrigation water quality improvement.

***Keywords*****—**Profit efficiency; Profit function; Environmental factors; OLS and MLE estimations; Rice Production; Vietnam



## I. Introduction

VIETNAM is the second highest rice exporting country in the world. Rice production is importance to Vietnamese economy in general and to its agriculture in particular. It occupies a high share in the country's Gross Domestic Product (GDP), contributing to about 20.4% of its GDP in 2006 (WB, 2008). However, as a result of rapid economic expansion and industrialization, land for rice production becomes smaller and less fertile.

Understanding the profitability of rice production becomes a major concern not only for farmers but also for policy makers. Particularly on how to shift the profit of rice production to profit frontier the condition of limited land. Besides, industrial development and the development of handicraft production are the major drivers cause water quality worse for rice production.

The were some studies related to efficiency measurements of rice production such as technical efficiency [1, 2] and productivity [3]. However, the research related to profit efficiency is limited in the literature. This research aims to estimate the three dimensions of profitability of rice production namely profit elasticity, profit loss and profit inefficiency. In addition, the environmental attributes affecting the profitability of rice production were determined.

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Environmental degradation is a consequence of economic and industrial development in developing countries particularly Viet Nam. Water pollution has also been a major concern as pollutants from industrial activities which contaminated the rice field and affected to the country's rice production. Omission of variables presenting environmental factors do not only affect to technical efficiency but also the profitability of rice [4]. Therefore, environmental factors such as soil quality, irrigation management, plant disease, and water pollution were primarily considered in this study.

Farmers may combat environmentally constraining factors by allocating more labor and adding more chemical fertilizer to the input bundle of their production [5]. These activities may lower the productivity and increase inefficiency. As a result, advanced technologies like using machinery, new seeds, and fertilizers become major factors to improve productivity.

The objectives of this research include the following. First, to determine the effects of environmental factors profit efficiency of rice production. Second, to estimate the profit loss of rice production due to environmental factors. Third, to provide recommendations to policy-makers on how to sustain rice production. Finally, contribute to the literature on the methodological development of estimating the impacts of environmental factors to rice production.

This paper is organized as follow. The next section will review the literature related to estimation of efficiency with special consideration to profit functions. In the third section, the detail description of research areas will be explained include the data of household survey. The framework for analysis and the econometric specification will be presented in the fourth section. The fifth section will be the major section with the results and discussions from model estimation. The final section will be the conclusions and policy implications.

## II. Analytical Framework for Measuring Profit Efficiency

### *A. Analytical Framework*

Economic efficiency is classified by two components: technical efficiency and allocative efficiency [6]. The profit function is combined both technical and allocative concepts in a profit relationships, and any errors in production decisions are translated into lower revenue [7] and hence, low profit efficiency .

The profit frontier approach is defined as

$$\pi_i = f(P_i, Z_i).\exp(\xi_i) \quad (1)$$

Where $\pi_i^{'}$ is the normalized profit of farm i, $P_j^{'}$ is the normalized input prices measured by dividing profit and input prices for output prices; $Z_k$ is the fixed inputs such as land and capital

This function can be estimated by OLS of MLE [8]

The OLS approach of profit function is written as

$$\ln \pi_i^{'} = \alpha + \sum_i \alpha \ln P_i^{'} + \alpha_L \ln Z_j^{'} + \xi_i \quad (2)$$

The translog profit function approach was used by Aigner et al. [9]; Meeusen & Broeck [10]; and Ali & Flinn [8]. The translog frontier form can be written as follows

$$\ln \pi_i = \alpha + \sum_i \alpha \ln P_i^{'} + \tfrac{1}{2}\alpha(\ln P)^2 + \alpha_L \ln Z + \tfrac{1}{2}\alpha(\ln Z)^2 + \sum\sum \alpha \ln Z \ln P + \xi \quad (3)$$

The paper used both from of profit frontier to compare the compares coefficients between different approaches of estimation.

Production inefficiency is measured by three components: technical, allocative and scale inefficiency.

Error terms is

$$\xi_i = v_i - u_i \quad (4)$$

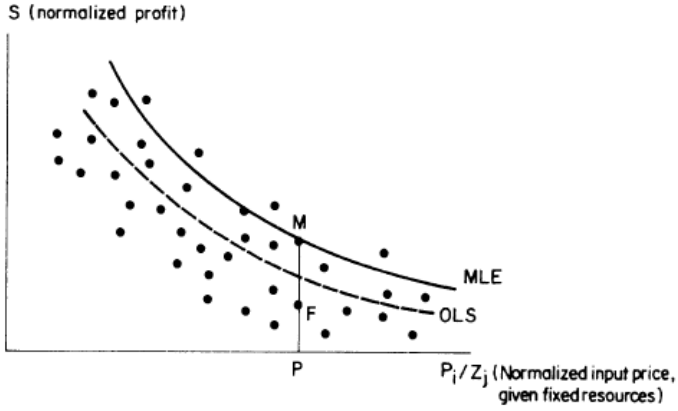
Production/Profit efficiency of individual farm i is defined as:

$$PE = E[\exp(-u_i) \mid \xi_i] = e[\exp(-\delta_0 - \sum_{d=1}^{D} \delta_d W_{di}) \mid \xi_i] \quad (5)$$

Besides farm and household characteristics, the environmental factors/constraints are used to estimate the efficiency such as irrigation, land suitability, insect and pest, weed infestation, weather variation (drought and storm), poor sold fertility status [4]. In this study, four environmental factor variables were selected such as the irrigation, plant disease, soil fertility and water quality.

### *B. Frontier MLE and OLS stochastic profit frontier*

Fig. 1 shows the differences in estimation of profit efficiency by MLE and OLS approaches. The OLS estimate the average of profit value while the MLE estimate the profit frontier [8]. . From the result of MLE, the profit loss can be derived by dividing the profit of individual farm for profit efficiency.




Source: [8]

Fig. 1 Relation between MLE and OLS in frontier estimation

## III. Research Area, Data And Econometric Specification

### *A. Research Area and Data*

The Red River Delta is the granary for rice production of all North Viet Nam. Although rice productivity has been gradually increasing in recent years due to adoption of advanced technologies, the production is still challenged with some constraints such as land fragmentation, soil degradation, and water pollution. One of the reasons this has contributed to this situation is the development of industrial production and handicraft production. Many industrial parks and production zones have been established near the rice fields, and the handicraft production villages also increase rapidly in quantity. Recently, the total number of craft villages has been increased dramatically to 2790 craft-villages located all over the country, and a half of them are located in the Red River region. This development makes the environment more polluted [11]. The problem of water pollution is in alarming stage with about 90 percent of the craft-villages violating environmental standards1.

Rice production in Bac Ninh province still plays an important role on the economic development of the province with some special rice species that are well-known for their flavor. The province has the highest number of craft villages (n=61) in the country. The water pollution from these craft villages cause some tens of hectares of land in the region uncultiavable and farm households become landless2.

This research is conducted in Bac Ninh province and one part of Ha Noi capital where rice production is still dominated by the local economy. In addition, these areas were selected to study the effect of water pollution on rice production in parallel with other environmental factors. Four communes were selected for the survey, namely: Phong Khe, Da Ton, Phu Dong, and Ninh Hiep. Phong Khe commune was located in Bac Ninh Province, while the three remaining communes were

[1] http://www.cand.com.vn/News/PrintView.aspx?ID=118604

[2] http://www.bacninh.gov.vn/Story/KHCNMoiTruong/BaoVeMoiTruong/2009/6/18427.html

located in nearby areas of Ha Noi Capital. Phong Khe and Da Ton communes were located in polluted areas, while the remaining two communes were located in non-polluted area.

In detail, Phong Khe is located near the paper recycling village and Da Ton is located near Sai Dong Industrial park. First, Da Ton is located near an industrial production zone named Sai Dong where pollutants from electronic companies were being discharged to the nearby river that flows to irrigation canal of the farmers. Next, Phong Khe is located in Bac Ninh province, which is famous for its handicraft production. The paper recycling is one of the major local industries in this commune.

This industry uses a lot of "cleaning and colorful chemicals". A big amount of wastewater is discharged directly into river without treatment. Therefore, almost all paddy rice areas are contaminated. Thirdly, Ninh Hiep commune is less polluted because it is not near any production areas and the irrigation was used from the big river namely Red River. Finally, Phu Dong commune is located in the last stage of a branch of Red River. Water Pollution in this commune is relatively low. The pollution source of water is mainly from household wastes, which does not affect rice production significantly.

TABLE I
DESCRIPTION OF VARIABLES

| Descriptions | Measure | Mean | Standard Deviation | Minimum | Maximum |
|---|---|---|---|---|---|
| *Output and inputs* | | | | | |
| Rice output | kg per year per farm | 1552.829 | 1198.26 | 90 | 10400 |
| Rice Yield | kg per sao per annum | 178.0096 | 44.49657 | 62.5 | 700 |
| Fertilizer price | '000VND per kg | 5.806547 | 1.895004 | 1.528205 | 20 |
| Pesticide price | '000VND per 100ml | 10.1832 | 9.296003 | .9782609 | 75 |
| Labor wage | '000VND per working day | 73.2728 | 11.94356 | 33.36355 | 110 |
| Land cultivated | Sao (1Sao=360m$^2$) | 8.472063 | 5.445733 | 0.5 | 40 |
| Capital (Rental cost for land preparation, harvesting, and transportation services) | '000VND per farm per annum | 713.3011 | 584.7483 | 0 | 4484 |
| *Environmental factors:* | | | | | |
| Soil quality | Dummy (1= good; 0= bad) | 0.5799458 | 0.4942374 | 0 | 1 |
| Irrigation | Dummy (0= N; 1= Y) | 0.9539295 | 0.2099224 | 0 | 1 |
| Diseases | Dummy (0= N; 1= Y) | 0.9945799 | 0.0735209 | 0 | 1 |
| Water Pollution | Dummy (0= N; 1= Y) | 0.5338753 | 0.4995285 | 0 | 1 |
| *Managerial variables* | | | | | |
| Age | Years | 48.12466 | 9.70016 | 26 | 75 |
| Male household head | Dummy (1= Male; 0=otherwise) | 0.495935 | 0.5006623 | 0 | 1 |
| HH size | Number of HH members | 4.791328 | 1.51526 | 2 | 10 |
| Education | Completed years of schooling | 6.336043 | 3.110436 | 0 | 12 |
| Experience in rice farming | Years of rice growing | 27.7561 | 12.00544 | 0 | 57 |
| Family Labor Ratio | Rate of No. of Family Labor and HH Size | 0.3946369 | 0.2967001 | 0 | 1 |
| Rice plots | Number of plots of rice fields that HH cultivate | 4.01626 | 2.317175 | 1 | 17 |
| Mono-cropping | Dummy (0= N; 1= Y) | 0.0813008 | 0.2736676 | 0 | 1 |
| Row-Seeding | Dummy(1=Row-seeding; 0=Broadcasting and others) | 0.1544715 | 0.3618909 | 0 | 1 |
| Credit | Dummy (1=borrow loan for rice production; 0=not borrow) | 0.0189702 | 0.1366049 | 0 | 1 |
| Total number of observations | | 349 | | | |

1USD equivalent to 20,000 VND in 2010

Survey on rice farmers was conducted in four communes of two provinces in the Red River Delta namely Ha Noi capital and Bac Ninh province. A total 369 rice farmers were interviewed using structure questionnaire. The survey was conducted during in the month of August 2010 by a group of enumerators after receiving a short training of the questionnaire. A pre-test was made to revise the questionnaire before the formal survey. After computing the profit, 20 households were deleted from the sample. Finally, the sample using for profit function estimation is 349 households.

A total of 20 households were deleted from the data set for the reason of minus values of production profit.

The dataset comprises of variables such as rice output (kg), rice yield (kg/sao), land (sao), the price of fertilizer('000VND/kg) , pesticide('000VND/100ml) and labor wage (000VND/working day per man) land input (Sao per farm), and Capital ('000VND/farm). All of these varialbes werecalculated with yearly basic. Only 5 inputs were used for model estimation.

The environmental factors measured were soil quality, irrigation, disease and water pollution. Managerials variables are age, gender, education, family labor ratio. In addition, rice plot, monocropping, adopting of row seeding technology are considered. Finally, access to credit was included.

Econometric Specification

Measuring efficiency has been started by Farrell [6], that explain the ability to produce a given level of output at lowest cost.

Ali & Flinn [8] estimated the profit efficiency by comparing the OLS (Ordinary Least Squared) and MLE (Maximum Likelihood Estimation) approaches to show the profitability of rice production in Pakistan.

Rahman [12]estimated rice profit efficiency by using translog function and added the farmer's characteristics in to inefficiency effects.

Kolawole [13] estimated the profit function by adding a constant to profit function to obtain the positive values and used Cobb-Douglass functional to estimate profit frontier.

The standard profit function assumes that markets for outputs and inputs are perfectly competitive.

$$\ln(\prod + \theta) = \ln f(P, W) + (V - U) \tag{6}$$

Where θ is a constant added to the profit of each firm in order to obtain positive values [13].

The farm profit is measured in term of Gross Margin(GM) which equal the difference between the total Total Revenue (TR) and Total Variable Cost (TVC)

$$GM(\Pi) = \Sigma(TR\text{-}TVC) = \Sigma(QP\text{-}WXi) \tag{7}$$

To estimate the impacts of environmental factors to profit efficiency, first the stochastic profit function is defined as:

$$\pi_i = f(P_i, Z_i).\exp(\zeta_i) \tag{8}$$

Where π is normalized profit of the ith farmer defined as gross revenue less variable cost, divided by farm output price; P is the vector of variable input prices faced by the ith farmer divided by output price; Z is the vector of fixed factor of ith farmer. $\zeta_i$ is an error term; and I = 1,…,n is the number of farms in the sample.

The model was fist development by [14] and applied by [12] and [15].

$$\ln \pi' = \alpha_0 + \sum_{j=1}^{n} \ln P_j' + \tfrac{1}{2} \sum_{j=1}^{n} \sum_{k=1}^{n} \tau_{jk} \ln P_j' \ln_k' + \sum_{j=1}^{n} \sum_{k=1}^{n} \phi_{jl} \ln P_j' \ln Z_l + \sum_{l=1}^{2} \beta_l \ln Z_l + \tfrac{1}{2} \sum_{l=1}^{2} \sum_{t=1}^{2} \varphi_{lt} \ln Z_l \ln Z_t + v - u \tag{9}$$

Where Ps, Pf, Po, Pp, Ph, Pw, Zli, Zti are price of seed, price of fertilizer, price of organic fertilizer, price of pesticide, price of herbicide, labor wage, land area, and capital of each farm, respectively.

$$u = \delta_0 + \sum_{d=1}^{n} \delta_d W_d + \omega \tag{10}$$

Where W is the variable representing socio-economic characteristics and environmental factors of the farm to explain inefficiency:(1) Age of household head;(2) Male household head; (3) Education (number of completed year of schooling); (4) Household size; (5) Family labor ratio; (6) Rice plots (the number of plots that household cultivate rice); (7) Mono-cropping (Dummy for household cultivate one crop per year; (8) Row seeding technique; (9) Household who borrow loan for rice production; (10) Dummy for soil quality; (11) Dummy for diseases; (12) Dummy for irrigation use (13) Dummy for water pollution.

## IV. Results And Discussions

### *A. Profit efficiency*

Comparing the result of OLS and MLE show the small change in coefficients when using different methods to estimate profit frontier. In addition, the OLS estimation result shows that 69% of dependent variable (profit) can be explained by independent variable (production inputs). This indicates that the production profit is close to the profit frontier.

Fertilizer price show the positive impact on profit. The reason is the chemical fertilizers are mixed. Therefore the price is estimated by the average price of all fertilizer per kg.

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Fertilizer price show the positive impact on profit. The reason is the chemical fertilizers are mixed. Therefore the price is estimated by the average price of all fertilizer per kg. And this show that the higher price of fertilizer means that the farmers use the higher quality of fertilizer. Therefore, it is rational to increase the profit.

The land area is positively effect to the profit. This means that the margin profit increase when the area of land cultivated is increase. Also, this shows the economics of scale in rice production.

TABLE II
MODEL ESTIMATIONS FOR PROFIT FUNCTION
F: fertilizer; P: pesticide; W: labor wage; C: capital; L: Land

| **Variables** | | **OLS Estimation** | | **MLE (Frontier Estimation)** | |
|---|---|---|---|---|---|
| | Parameters | Coefficients | *t*-ratio | Coefficients | z-value |
| *Profit function* | | | | | |
| Constant | $\alpha_0$ | 6.029*** | 6.85 | 6.324*** | 8.14 |
| $\ln P'_F$ | $\alpha_1$ | 0.228 | 0.28 | 0.784 | 1.1 |
| $\ln P'_P$ | $\alpha_2$ | 0.163 | 0.38 | 0.344 | 0.9 |
| $\ln P'_W$ | $\alpha_3$ | -0.615 | -1.14 | -0.509 | -1.09 |
| ½ $\ln P'_F$ x $\ln P'_F$ | $\alpha_4$ | -0.475** | -2.44 | -0.451*** | -2.88 |
| ½ $\ln P'_P$ x $\ln P'_P$ | $\alpha_5$ | -0.042 | -0.7 | -0.064 | -1.19 |
| ½ $\ln P'_W$ x $\ln P'_W$ | $\alpha_6$ | 0.523** | 2.28 | 0.466*** | 2.44 |
| $\ln P'_F$ x $\ln P'_P$ | $\alpha_7$ | -0.114 | -1.23 | -0.025 | -0.31 |
| $\ln P'_F$ x $\ln P'_W$ | $\alpha_8$ | 0.244 | 0.96 | 0.210 | 0.99 |
| $\ln P'_P$ x $\ln P'_W$ | $\alpha_9$ | -0.019 | -0.12 | -0.031 | -0.24 |
| lnC | $\alpha_{10}$ | 0.138 | 0.63 | 0.045 | 0.24 |
| ½ lnC x lnC | $\alpha_{11}$ | -0.028* | -1.61 | -0.003 | -0.18 |
| $\ln P'_F$ x lnC | $\alpha_{12}$ | -0.128 | -1.1 | -0.236** | -2.3 |
| $\ln P'_P$ x lnC | $\alpha_{13}$ | -0.024 | -0.44 | -0.0349 | -1.14 |
| $\ln P'_W$ x lnC | $\alpha_{14}$ | -0.028 | -0.35 | -0.027 | -0.39 |
| $\ln P'_F$ x lnL | $\alpha_{15}$ | 0.037 | 0.27 | 0.115 | 0.98 |
| $\ln P'_P$ x lnL | $\alpha_{16}$ | 0.005 | 0.08 | 0.0511 | 0.53 |
| $\ln P'_W$ x lnL | $\alpha_{17}$ | 0.025 | 0.16 | 0.036 | 0.27 |
| lnL | $\alpha_{18}$ | 0.013** | 0.03 | -0.010 | -0.03 |
| ½ lnL x lnL | $\alpha_{19}$ | 0.353*** | 7.34 | 0.341*** | 7.58 |
| R-squared | | 0.690 | | | |
| No. of Observations | | 349 | | 349 | |
| Variance para. | | | | | |
| ln σv 2 | | | | -4 | -12.66 |
| ln σu 2 | | | | -1.85 | -12.42 |
| σ 2 = σu 2 + σv 2 | σ2 | | | 0.170 | |
| λ = σu /σv | λ | | | 3.313 | |

*** significant at 1 percent level (p<0.01), ** significant at 5 percent level (p<0.05), * significant at 10 percent level (p<0.10)

TABLE III
ESTIMATION OF PROFIT ELASTICITIES

| Prices and fixed inputs | Profit elasticity |
|---|---|
| Rice price | 0.690 |
| Fertilizer price | 0.072 |
| Pesticide price | -0.086 |
| Labor wage | 0.956 |
| Land area | 1.257 |
| Capital | -0.090 |

Source: Authors' estimation

Land area dominates the profit share. Increasing the land area by 1%,will increase the profit by 1.2%If the price of rice increases by 1%, the profit will increase 0.7%. If the price of fertilizer increases 1%, the profit will increase 0.07%.

If the price of pesticide increases by 1%, the profit will reduce by 0.08%. If the labor wage increases by 1%, the profit will increase 0.9%. If the capital increases by 1%, the profit will decrease 0.09%. In this study, the increase in the price of fertilizer means that the farmers will get the higher quality of fertilizer and it will indirectly increase the yield. The increase in labor wage increase means the farmers use more hired labor force than home labor and it also increases the yield. The capital lowers the profit because capital is consider as inputs and it is better if the farmer can rent the capital.

*B. Profit inefficiency and Profit-loss*

TABLE IV
ESTIMATION FOR PROFIT INEFFICIENCY

| Variables | Para. | Coefficients | Standard Errors | t-ratio |
|---|---|---|---|---|
| Constant | $\beta_0$ | 0.351*** | 0.1727 | 2.04 |
| Age | $\beta_1$ | 0.001 | 0.0012 | 1.19 |
| Male HH head | $\beta_2$ | -0.061** | 0.0231 | -2.67 |
| Education | $\beta_3$ | -0.003 | 0.0038 | -0.94 |
| HH size | $\beta_4$ | 0.060** | 0.0264 | 2.29 |
| Family labor ratio | $\beta_5$ | -0.042** | 0.0240 | -1.75 |
| Rice plots | $\beta_5$ | 0.052** | 0.0238 | 2.22 |
| Mono-cropping | $\beta_7$ | 0.053 | 0.0457 | 1.16 |
| Row-seeding technique | $\beta_8$ | -0.060** | 0.0348 | -1.74 |
| Credit | $\beta_9$ | -0.071 | 0.0861 | -0.83 |
| *Env. Factors* | | | | |
| Soil quality | $\delta_1$ | 0.074 | 0.1468 | 0.51 |
| Diseases | $\delta_2$ | -0.047** | 0.0235 | -2.01 |
| Irrigation | $\delta_3$ | -0.139** | 0.0577 | -2.41 |
| Water Pollution | $\delta_4$ | 0.043** | 0.0259 | 1.67 |
| Total number of observations | | 349 | | |

*** significant at 1 percent level (p<0.01), ** significant at 5 percent level (p<0.05), * significant at 10 percent level (p<0.10).

Farm household can maximize profit efficiency by minimizing profit inefficiencies. The factors contribute positively to inefficiencies are household size, land plots and water pollution. Besides, the factors contribute negatively to inefficiencies are male household head, plant diseases and irrigation. The disease and irrigation variables are not well defined in the data. The reason is the percentage of sample that was attacked by disease is 95% and irrigation apply is 99% (Table 1) . The reasons to include these variables is to show the evidence that almost of the farmers got disease attack and apply irrigation in rice production.

Age of household head increases profit inefficiency. The young farm household head can work more effectively that the older ones.

Household size increases profit inefficiency because the household with more member cannot use the home labor better the smaller household ones. The household with large household size composes mainly of dependents such as the elders and the children. They do not contribute well with the labor force to farming activities.

It is similar with the family labor ratio. The household with more members are in the range of working age will decrease the profit efficiency because they can use more of their home labor in rice production rather than their rental labor force.

The fragmentation of land is measured by the quantity of farm plots. The higher number of land plots may increase production cost in rice production [16] or reduce the production profit as a result. This is a critical issue in the Northern region of Vietnam as discussed in the previous literature [17]. In this study, the number of plot shows that increase of profit inefficiency or decrease profit of rice production. This indicates that number of plots can increase production cost for rice producer households.

Mono production in rice farming means that the farm household cultivates their land only one crop per year. This is clearly increase profit inefficiency. The reason for this is because of rice production is not profitable or the can find other earning opportunities than producing rice.

Appling Row-seeding technique in rice production can decrease cost and increase productivity of rice production. This is the technique that farm household in the Red River's Delta of Viet Nam should use in rice farming under the condition of not using machine for seeding.

The household with decrease can decrease profit efficiency. The diseases in rice production are popular now in Viet Nam in general and in the Red River's Delta in particular. However, the farmers use a lot of pesticide and it can combat the diseases of rice plant. The farmers understand well about the disease situation and they can prepare well to cure them.

Water pollution is a serious problem now for rice production. The pollution sources are from industries, handicraft production where they discharge their waste water without any treatments. In this study, the rice producers in polluted region get loss of their profit because they have to spend more for labor and other input cost to abate pollution such as chemical fertilizer, organic fertilizer and pesticides.

TABLE V
PROFIT-LOSS BY THE KEY CONSTRAINTS

| Farm-specific Characteristics | N | Actual profit per ha | Estimated profit-loss per ha[a] | Profit efficiency |
|---|---|---|---|---|
| *Profit-loss by household size* | | | | |
| Small household size | 255 | 11198.2 | 2758.276 | .7648362 |
| Large household size | 94 | 10191.03 | 3169.689 | .7140469 |
| t-ratio | | 1.4460* | -2.2949** | 2.9908*** |
| *Profit-loss by family labor ratio* | | | | |
| Low family labor ratio | 171 | 9470.631 | 2679.177 | .7301912 |
| High family labor ratio | 178 | 12325.95 | 3051.527 | .7712975 |
| t-ratio | | -4.7532*** | -2.3412** | -2.7218*** |
| *Profit-loss by farm plots* | | | | |
| Some farm plots | 212 | 10803.16 | 2562.956 | .7655034 |
| Many farm plots | 137 | 11118.45 | 3342.805 | .7289557 |
| t-ratio | | -0.4970 | -4.9150*** | 2.3577** |
| *Profit-loss by mono cropping* | | | | |
| Not Mono cropping | 325 | 11218.7 | 2885.818 | .7443083 |
| Mono cropping | 24 | 6975.811 | 2642.512 | .6857239 |
| t-ratio | | 3.5260*** | 0.7690 | 1.8026** |
| *Profit-loss by row seeding technique* | | | | |
| Not use row seeding technique | 292 | 10501.35 | 2927.031 | .7396094 |
| Use row seeding technique | 57 | 13107.07 | 2572.244 | .8103105 |
| t-ratio | | -3.1522*** | 1.6431* | -3.4848*** |
| Environmental factor effects | | | | |
| Farm has plant disease | 2 | 10225.69 | 918.6785 | .900259 |
| Farm has no plant disease | 347 | 10930.97 | 2880.328 | .7502972 |
| t-ratio | | -0.1718 | -1.8570** | 1.4883* |
| *Profit-loss by soil quality* | | | | |
| Not Soil fertility | 140 | 9560.321 | 2778.726 | .7229509 |
| Soil fertility | 209 | 11842.36 | 2929.615 | .7700504 |
| t-ratio | | -3.6787*** | -0.9241 | -3.0663*** |
| *Profit-loss by irrigation* | | | | |
| Farm without irrigation | 15 | 7009.819 | 3597.521 | .6195658 |
| Farm with irrigation | 334 | 11102.84 | 2836.372 | .7570664 |
| t-ratio | | -2.7066*** | 1.9369** | -3.7273*** |
| *Profit-loss by water pollution* | | | | |
| Farm without water pollution | 170 | 12439.08 | 2959.261 | .7763847 |
| Farm with water pollution | 179 | 9490.8 | 2783.446 | .7271969 |
| t-ratio | | 4.9179*** | 1.0986 | 3.2716*** |
| All farms | 349 | 10926.93 | 2869.086 | .7511566 |

[a] Profit loss is computed from maximum profit given prices and fixed factor endowments.
Maximum profit per hectare is computed by dividing the actual profit per hectare of individual farms by its efficiency score.
*Significant at 10% (p<0.10); **Significant at 5% (p<0.05); ***Significant at 1% (p<0.01).

## V. CONCLUSIONS AND POLICY IMPLICATIONS

The estimation result shows the similar coefficients between OLS and MLE approaches. The inclusion of environmental factors show significantly effects on profit efficiency. In other words, the environmental changes the profit efficiency of rice production. Farmers can get about $150 of profit per hectare if the rice farmers can control the production constraints. Therefore, In order to maximize profit, rice farm household has to overcome some obstacles of their household characteristics such as labor and household size.

However, there are some issues that related to policy that the government should involve in to support the farmers in order to maximize their profit such as land consolidation to minimize the number of farm plots and increase the farm size, technology and water quality control. The advance technology such as row seed tools or machine should be apply and promoted in rice farming. These are the policy implications that the government should consider to sustain rice production in the Red River Delta and for the country as well.

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