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Inefficiency in Rice Production and Land Use: A Panel Study of Japanese Rice Farmers

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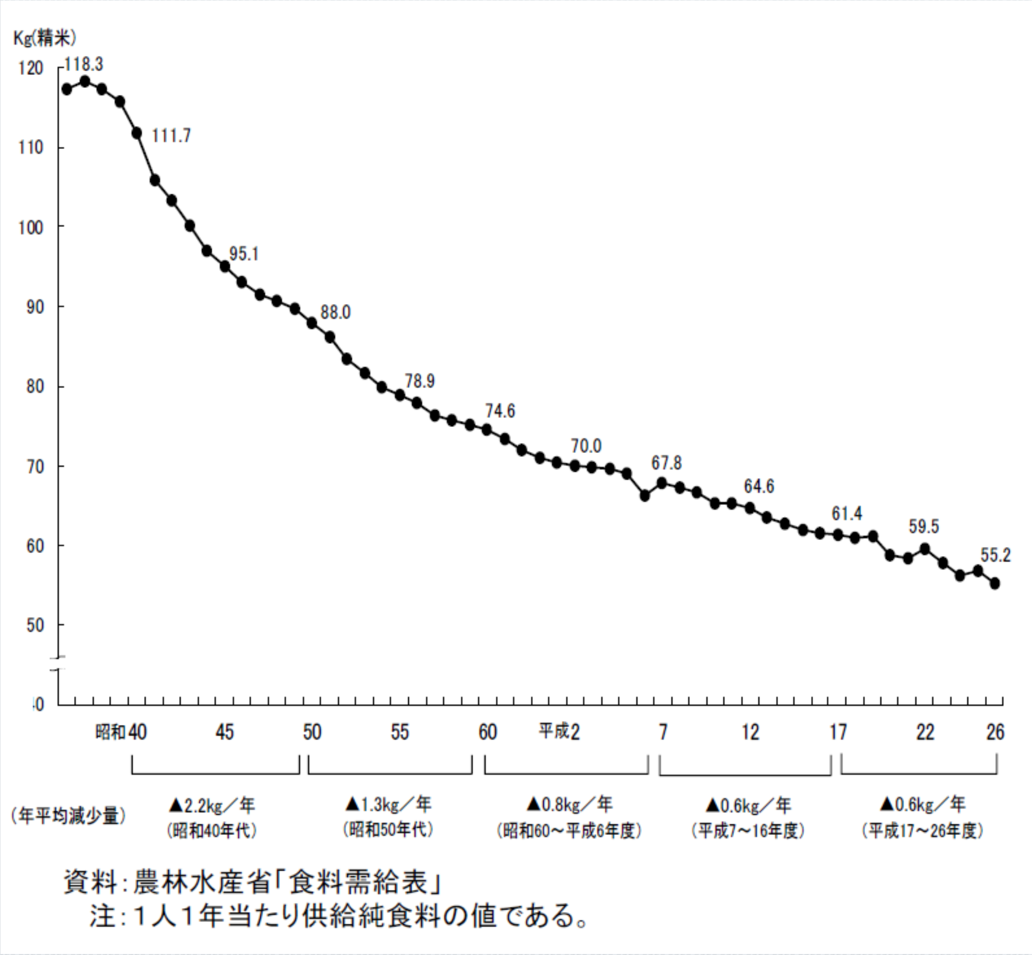
1. Introduction

- Decreasing trend of Japan’s demand for rice

  Annual consumption of rice per capita



118 kg per capita
in 1962

55 kg per capita
in 2014

Figure 1　Yield of and Demand for Rice as a Staple Food

Source: Ministry of Agriculture, Forestry and Fisheries, *Situations about Rice, Basic Principles on Demand and Supply of Rice and Price Stabilization*

Yield exceeded demand almost every year!

➢ Rice production adjustment policy

Promote a shift of crops from production of rice as a stable food to soybeans, grains and “new demand rice” mainly used as animal feed

However, if rice as a staple food is produced by *inefficient* farmers, a large tax burden will be incurred to maintain the price of rice.

2. Purpose of the Paper

Empirical analysis of the efficiency in production by the rice-producing farmers, using the panel data from the Rice Production Cost Statistics (*Kome Seisanhi Chosa Tokei*) reported by the Ministry of Agriculture, Forestry and Fisheries

Specifically,

- The stochastic frontier production function with four production factors (land, labor, capital stock, and materials) is estimated.
- The inefficiency indices of production are calculated.
- Based on the inefficiency indices, the efficient and inefficient rice producers are identified, and the factor demand behavior and the characteristics of the arable land utilization for rice production are compared.

3. Summary of the Results

1. On inefficiency indices:

The estimate of inefficiency in production was robust, irrespective of the type of production function or the probability distribution of the inefficiency.

2. Characteristics of the *inefficient* rice farmers

1) The number of parcels is large

A 'parcel' refers to a gathering or complex consisting of several neighboring plots

2) Low profit and income per 10 are, and large loan balance and subsidies per 10 are

3) Low land, capital, and labor productivity

4) Majority of the farmers own farms with micro plots, and few farmers own farms with relatively large-scale plots

5) Low arable land utilization rate for rice production

6) High proportion of “certified farmers”

What is a “certified farmer” ?

In order to be selected as a certified, a farmer passes through a process wherein she/he submits an agricultural management improvement plan to the local municipals, and they, in turn, certify for a period of 5 years.

The target for expansion of management scale over the coming 5 years and the goals for attaining efficiency of agricultural management should be described in the agricultural management improvement plan.

Advantage of being a certified farmer

- Grants and increases in the subsidies related to agricultural production, mainly switching to new crops
- Low interest finance from the Agriculture JA Bank and the Japan Finance Corporation

Disadvantage of being a certified farmer

- Various burdensome official procedures
- Cooperation in production adjustment for rice was a requirement at the stage of applying to a certified farmer prior to 2009

3.Characteristics of dynamic factor demand

Slow adjustment of labor input by inefficient rice producers without responding to a change in wages

4. Determinants of the cultivated area used for rice production

The higher the proportion of farm area in small plots, the more likely that the producer would reduce arable land utilization for rice production; and these effects were larger for the efficient producer.

Certified farmers reduced arable land cultivation for rice production, and the extent of this reduction was larger for efficient producers.

In other words, the more efficient a certified farmer is, the more likely it is that he would use a field for something other than rice cultivation.

The productivity of rice production may decline further in the future.

4. Data Set and their Characteristics

- Rice Production Cost reported by the Ministry of Agriculture, Forestry and Fisheries (2008~2013)

- The sample farmers: agricultural households that sold at least 600 kg of unpolished rice

- The number of observations: 5,543

Data of major variables

1) Yield (Y): quantity of rice produced as the main product (kg)
2) Labor input (N): labor time spent on rice cultivation, including both family labor and hired labor (hours)
3) Land (L): area planted in rice (are)
4) Capital stock (K): buildings and structures, land improvement equipment, automobiles, agricultural machinery, and tools deflated by the corresponding price indices (ten thousand yen in 2010 price)

5) Materials (M) : five materials (seed and seedling, fertilizer, agricultural chemicals, light, heat and power, and various other materials costs) deflated by the corresponding price indices
(ten thousand yen in 2010 price)

6) Prices:

Production price (p)

Wage rate (w)

Land rent (p_L)

Rental price of capital (p_K)

Materials price (p_M)

Table 2 Descriptive Statistics of Major Variables

	mean	median	standard deviation
Yield of rice (kg)	21891	10290	31021
Area planted for rice production (a)	416.0	199.0	578.6
Labor input (hours)	816.2	515.0	914.7
Capital stock (ten thousand yen) 1)	400.3	196.5	583.7
Material input (ten thousand yen) 2)	100.7	49.3	139.3
Land productivity (kg/a.)	51.4	51.7	7.4
Labor productivity (kg/hour)	23.5	21.0	12.8
Capital productivity (kg/ten thousand yen)	291.5	60.0	5276.9
Arable land utilization as rice production (%)	74.2	75.6	18.2
Proportion of farm area not disposed of or in lots of less than 10 a (%)	17.4	5.1	26.8
Proportion of farm area in lots more than or equal 10 a and less than 20 a (%)	27.0	18.6	28.2
Proportion of farm area in lots more than or equal 20 a and less than 30 a (%)	27.0	18.6	29.0
Proportion of farm area in lots more than or equal 30 a and less than 50 a (%)	18.6	0.0	25.7
Proportion of farm area in lots more than or equal 50 a (%)	10.0	0.0	23.2

Notes: 1), 2) real values in 2010 price

Source: Ministry of Agriculture, Forestry and Fisheries, Rice Production Cost Statistics

5. Identification and Estimation of Inefficiency in Production

- Specification of stochastic frontier production function

$$\ln Y_{it} = f(lnN_{it}, lnK_{it}, lnL_{it}, lnM_{it}) - u_{it} + v_{it}$$

where Y_{it}: output
N_{it}: labor input
K_{it}: capital stock
L_{it}: planted area for rice
M_{it} : material input
u_{it} : random variable for inefficiency
$u_{it} \geq 0$
v_{it} : disturbance term

- Two types of production function

1. Cobb-Douglas production function
2. Translog production function

- Two types of probability distribution for inefficiency

1. half-normal
2. truncated normal

- Distribution of v_{it}

    i.i.d. $\mathrm{N}(0, \sigma_v^2)$

- Other explanatory variables
  - Year dummies
  - Regional dummies for 10 regions
    （Hokkaido, Tohoku, south Kanto, north Kanto and Koshin, Hokuriku, Tokai, Kinki, Chugoku, Shikoku, and Kyushu）

- Estimation results by ML method
    Table 3

Table 3 Estimation Results of Stochastic Frontier Production Function (1)

	(1) haf-normal	(2)	(3) truncated-normal	(4)
lnN	0.0141 **	-0.0854	0.0141 **	-0.0852
	(2.46)	(-0.55)	(2.44)	(-0.55)
lnK	0.0048 **	-0.1589 ***	0.0048 **	-0.1586 ***
	(2.51)	(-2.96)	(2.51)	(-2.97)
lnL	0.9397 ***	1.0582 ***	0.9398 ***	1.0551 ***
	(115.56)	(3.84)	(115.14)	(3.90)
lnM	0.0567 ***	0.2854	0.0568 ***	0.2879
	(6.64)	(0.90)	(6.63)	(0.93)
$(\ln N)^2$		0.0047		0.0047
		(0.55)		(0.55)
(lnN)(lnK)		0.0044		0.0046
		(1.10)		(1.13)
(lnN)(lnL)		-0.0047		-0.0048
		(-0.26)		(-0.27)
(lnN)(lnM)		0.0005		0.0003
		(0.03)		(0.02)
$(\ln K)^2$		0.0005		0.0005
		(0.69)		(0.68)
(lnK)(lnM)		0.0166 ***		0.0166 ***
		(2.58)		(2.59)
(lnK)(lnL)		-0.0176 ***		-0.0177 ***
		(-2.90)		(-2.92)
$(\ln L)^2$		0.0113		0.0111
		(0.67)		(0.67)
(lnL)(lnM)		0.0033		0.0038
		(0.10)		(0.11)
$(\ln M)^2$		-0.0187		-0.0188
		(-0.92)		(-0.94)
μ			0.0186	0.0149
			(0.47)	(0.37)
σ_u	0.1788 ***	0.1778 ***	0.0298 ***	0.0299 ***
	(42.24)	(42.03)	(6.37)	(6.23)
σ_v	0.0926 ***	0.0926 ***	0.0086 ***	0.0086 ***
	(84.86)	(84.75)	(41.98)	(41.92)
Number of observations	5408	5408	5408	5408

Notes: The coefficient estimates of year and regional dummies are suppressed.

➢ Summary of the estimation results

1) All of the coefficient estimates of the Cobb-Douglas production function are significantly positive (increasing returns to scale)
2) Many of the coefficient estimates of the translog production function are not significant due to multicollinearity
3) The estimate of the inefficiency location parameter μ of truncated normal distribution is not statistically significant $\longrightarrow$ Half normal

➢ Descriptive statistics of inefficiency indices

$$E[u_{it} | \varepsilon_{it}] \qquad \text{where } \varepsilon_{it} \equiv v_{it} - u_{it}$$

Table 4

Comparison of Production Inefficiency Indices

production function	probability distribution of inefficiency	mean	median	standard deviation
Cobb-Douglas	Half-normal	0.1102	0.0797	0.0867
Translog	Half-normal	0.1098	0.0800	0.0864
Cobb-Douglas	Truncated normal	0.1418	0.1211	0.0946
Translog	Truncated normal	0.1407	0.1192	0.0941

- The correlation coefficient of the inefficiency indices between the Cobb-Douglas production function and the translog production function is 0.9983 for both types of probability distributions

In the subsequent analysis, we assume the half-normal for the inefficiency distribution, and the Cobb-Douglas for the production function

6. Comparison of Behavioral Characteristics between Efficient and Inefficient Rice Producers

- Based on the median of the inefficiency indices, the rice producers are divided into an efficient producer group and an inefficient producer group, and the characteristics of their respective behaviors are examined

Table 6 Comparison of Characteristics between Efficient and Inefficient Rice Producers

	inefficient producers	efficient producers	test statistics of mean difference
Number of parcels	4.5	4.25	2.12**
Area planted for rice production (a)	408.6	423.5	-0.95
Income per 10 a (yen)	13620.6	24126.6	-8.71***
Outstanding loan balance per 10 a (yen)	15854.5	11702.2	3.99***
Land productivity (kg/a)	47.7	55.1	-42.9***
Labor productivity (kg/hour)	142.1	442.7	-2.10**
Capital productivity (kg/ten thousand yen)	21.9	25.1	-9.25***
Arable land utilization as rice production (%)	73.5	74.9	-2.69***
Net receipt of mutual aid money per 10 a (yen)	-135.5	-376	3.41***
Proportion of farm area not disposed of or in lots of less than 10 a (%)	18.7	16.1	3.58***
Proportion of farm area in lots more than or equal 10 a and less than 20 a (%)	28.4	25.6	3.70***
Proportion of farm area in lots more than or equal 20 a and less than 30 a (%)	26.8	27.3	-0.74
Proportion of farm area in lots more than or equal 30 a and less than 50 a (%)	17.9	19.2	-1.96*
Proportion of farm area in lots more than or equal 50 a (%)	8.2	11.7	-5.55***
Proportion of certified farmers (%)	50	44.5	4.09***
Price of the harvested rice per kg (yen)	218.2	217.5	0.73

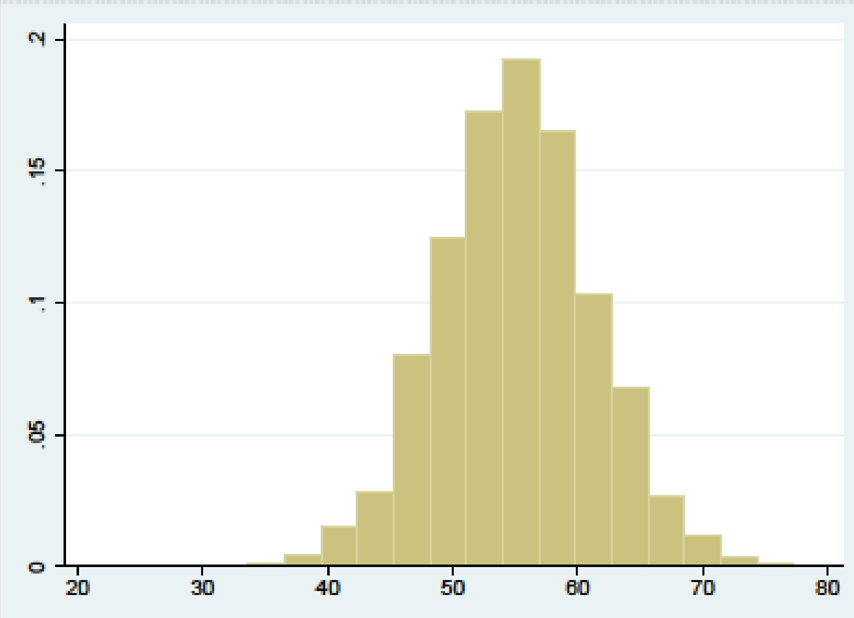
Notes: *, **, *** significant at 10%, 5%, 1% level, respectively

➢ Characteristics of the *inefficient* rice farmers

1) The number of parcels is large
   The agricultural land is more fragmented.
2) Low profit and income per 10 are, and large loan balance and subsidies per 10 are
3) Low land, capital, and labor productivity
4) Majority of the farmers own farms with micro plots (less than 20a), and few farmers own farms with relatively large-scale plots (more than 30a)
5) Low arable land utilization rate for rice production
6) High proportion of “certified farmers”

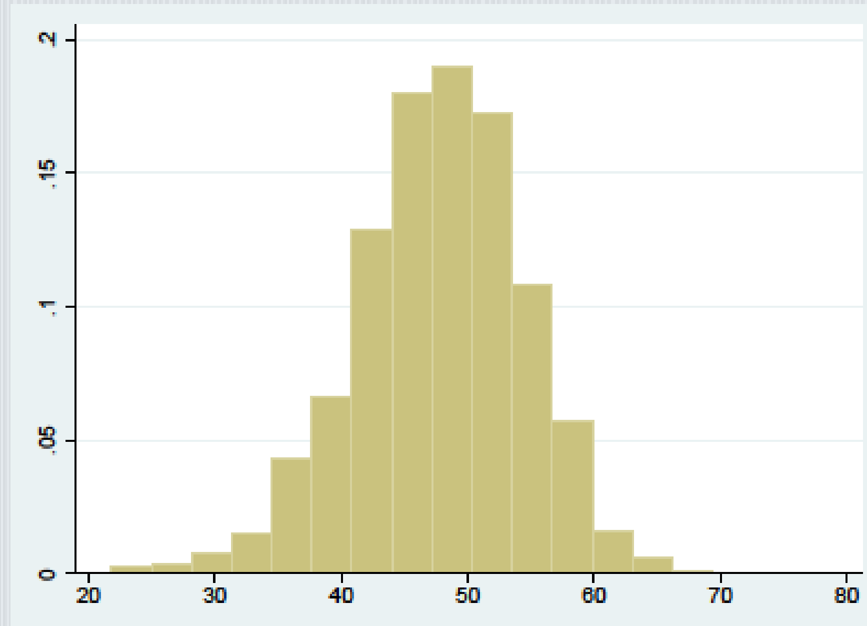
➢Histograms of land productivity for efficient and inefficient producer group

(a) Efficient Rice Producer



kg/a
mean = 55.15kg

(b) Inefficient Rice Producers



kg/a
mean =47.69kg

7. Inefficiency in Production and Factor Demand

1. Production inefficiency and static factor demand

We examine how inefficiency in production will affect static factor demand, given land input

$$Y = F(K, N, M, \bar{L})e^{-u}$$

where Y: output

$K, N, M, \bar{L}$: capital stock, labor, material and land

u: non-negative inefficiency

- Factor demand functions derived from profit maximization are expressed as follows:

$$K^* = g_K\left(\frac{p_K}{p}, \frac{w}{p}, \frac{p_M}{p}, \bar{L}, u\right)$$

$$N^* = g_N\left(\frac{p_K}{p}, \frac{w}{p}, \frac{p_M}{p}, \bar{L}, u\right)$$

$$M^* = g_M\left(\frac{p_K}{p}, \frac{w}{p}, \frac{p_M}{p}, \bar{L}, u\right)$$

where p, p_K, w, p_M: output price, rental price of capital, wage rate and materials price

Proposition:

The more a rice producer diverges from the production frontier, the more the factor demand also diverges from the optimal level when $\frac{\partial^2 Y}{\partial x_i \partial x_j} > 0$ (x:factor input, $i \neq j$).

To examine this proposition, the logarithmic linear factor demand function, which takes inefficiency into consideration, is estimated

Specification of static factor demand function

$$lnK_{it} = \beta_{0K} + \beta_{1K} ln\left(\frac{p_K}{p}\right)_{it} + \beta_{2K} ln\left(\frac{w}{p}\right)_{it} + \beta_{3K} ln\left(\frac{p_M}{p}\right)_{it} + \beta_{4K} ln\overline{L_{it}} - u_{K,it} + v_{K,it}$$

$$lnN_{it} = \beta_{0N} + \beta_{1N} ln\left(\frac{p_K}{p}\right)_{it} + \beta_{2N} ln\left(\frac{w}{p}\right)_{it} + \beta_{3N} ln\left(\frac{p_M}{p}\right)_{it} + \beta_{4N} ln\overline{L_{it}} - u_{N,it} + v_{N,it}$$

$$lnM_{it} = \beta_{0M} + \beta_{1M} ln\left(\frac{p_K}{p}\right)_{it} + \beta_{2M} ln\left(\frac{w}{p}\right)_{it} + \beta_{3M} ln\left(\frac{p_M}{p}\right)_{it} + \beta_{4M} ln\overline{L_{it}} - u_{M,it}$$

$$+ v_{M,it}$$

$u_{K,it}, u_{N,it}, u_{M,it}$: inefficiency in capital stock, labor and materials

Descriptive statistics of the inefficiency indices in the three-factor demand functions

Table 8 Inefficient Indices of Production and Factor Demand

(1) Mean, Median and Standard Deviation

factor demand	mean	median	standard deviation
lnY	0.1102	0.0797	0.0867
lnK	0.4702	0.3769	0.3568
lnN	0.5443	0.4591	0.3922
lnM	0.2843	0.2334	0.2113

(2) Correlation Coefficient

	lnY	lnK	lnN	lnM
lnY	1.0000			
lnK	0.3560	1.0000		
lnN	0.2396	0.2437	1.0000	
lnM	0.2305	0.3548	0.4799	1.0000

2. Production inefficiency and dynamic factor demand

Comparison of the dynamic adjustment processes of factor demand between the efficient and the inefficient rice producers

Specification of dynamic factor demand function

$$lnK_{it} = \gamma_{0K} + \gamma_{1K} ln\left(\frac{p_K}{p}\right)_{it} + \gamma_{2K} ln\left(\frac{w}{p}\right)_{it} + \gamma_{3K} ln\left(\frac{p_M}{p}\right)_{it} + \gamma_{4K} lnK_{i,t-1} + v_{K,it}$$

$$lnN_{it} = \gamma_{0N} + \gamma_{1N} ln\left(\frac{p_K}{p}\right)_{it} + \gamma_{2N} ln\left(\frac{w}{p}\right)_{it} + \gamma_{3N} ln\left(\frac{p_M}{p}\right)_{it} + \gamma_{4N} lnN_{i,t-1} + v_{N,it}$$

$$lnM_{it} = \gamma_{0M} + \gamma_{1M} ln\left(\frac{p_K}{p}\right)_{it} + \gamma_{2M} ln\left(\frac{w}{p}\right)_{it} + \gamma_{3M} ln\left(\frac{p_M}{p}\right)_{it} + \gamma_{4M} lnM_{i,t-1} + v_{M,it}$$

➢Estimation results by System GMM

Table 9 Estimation Results of Dynamic Factor Demand Function

(1) Efficient Rice Producers

	lnK		lnN		lnM	
$\ln(p_K/p)$	-1.0522	***	0.0019		0.0081	
	(-15.21)		(0.06)		(0.23)	
$\ln(w/p)$	-0.3179		-0.8627	***	-0.4881	**
	(-1.27)		(-3.09)		(-2.09)	
$\ln(p_M/p)$	1.679	***	0.9617	**	0.4562	
	(5.72)		(2.47)		(1.47)	
lagged dependent variable	0.4795	***	0.5259	***	0.3995	***
	(6.73)		(5.03)		(3.89)	
Constant term	10.8729	***	9.6922	***	11.2654	***
	(5.52)		(3.46)		(4.26)	
Test statistics of serial correlation	0.6744		-0.1362		0.453	
Number of observations	1551		1552		1552	

(2) Inefficient Rice Producers

	lnK		lnN		lnM	
$\ln(p_K/p)$	-1.0701	***	0.0855	**	0.1008	***
	(-26.72)		(2.54)		(2.89)	
$\ln(w/p)$	0.1566		0.1925		0.5237	***
	(0.74)		(1.31)		(3.09)	
$\ln(p_M/p)$	0.9762	***	-0.1884		-0.601	***
	(4.05)		(-1.15)		(-3.07)	
lagged dependent variable	0.3964	***	0.6181	***	0.658	***
	(7.43)		(4.22)		(7.86)	
Constant term	7.1921	***	1.4985		0.9046	
	(4.03)		(1.09)		(0.53)	
Test statistics of serial correlation	-1.2881		-1.1023		-1.1814	
Number of observations	1907		1907		1907	

Notes: The coefficient estimates of year dummies are suppressed.

- Comparison of dynamic labor demand between the efficient and the inefficient producers

1) The adjustment speed of labor is faster for efficient producers (0.4741) than for inefficient producers (0.3819).

2) When a wages rises, efficient producers immediately reduce labor input. The long run wage elasticity is -1.8197; thus, large labor adjustments occur over the longer term.

3) Inefficient producers do not make any adjustments of labor input in either the short or long run even if there is a change in wages.

8. Determinants of Arable Land Utilization as Rice Production

- Comparison of the determinants of the arable land utilization as rice production between efficient and inefficient producer group
- We assume that the proportion of arable land used for rice production is determined by the economic circumstances of rice producers *in the previous year*.
- The determinants of arable land utilized for rice production are divided into three groups

1. Performance of producers
    1) Land productivity
    2) Outstanding loan balance
    3) Crop prospects relative to normal year
2. Attributes of the fields
    1) Number of parcels of the fields
    2) Area distribution of the farm plots
3. Organizational characteristics of farmers
    1) Participation of farmers in agricultural production organizations, such as cultivation accords, joint utilization, and consignment
    2) Whether a farmer is certified or not

Table 10 Estimation Results of the Determinants of Arable Land Utilization as Rice Production

	efficient rice producer		inefficient rice producer	
Land productivity	0.0022	**	0.0038	***
	(2.08)		(3.95)	
Number of parcels	0.0027	*	0.002	**
	(1.95)		(2.00)	
Dummy for participation in cultivation accords	0.0084		0.0239	
	(0.37)		(1.09)	
Dummy for participation in joint utilization	-0.0267		-0.0508	***
	(-1.47)		(-3.38)	
Dummy for participation in consignment contract	-0.0643	**	-0.0542	**
	(-2.02)		(-2.22)	
Outstanding loan balance	0.0015		0.0012	
	(1.18)		(1.49)	
Crop prospects relative to normal years	-0.1074	*	-0.1557	***
	(-1.79)		(-3.38)	
Proportion of farm area not disposed of or in lots of less than 10 a	-0.1001	***	-0.0541	*
	(-3.38)		(-1.77)	
Proportion of farm area in lots more than or equal 10 a and less than 20 a	-0.0841	***	-0.003	
	(-3.07)		(-0.10)	
Proportion of farm area in lots more than or equal 20 a and less than 30 a	-0.0797	***	-0.0038	
	(-3.01)		(-0.13)	
Proportion of farm area in lots more than or equal 30 a and less than 50 a	-0.0283		-0.0172	
	(-0.98)		(-0.59)	
Dummy for certified farmers	-0.0646	***	-0.0313	***
	(-5.48)		(-2.98)	
Determinants of coefficient	0.1698		0.1361	
Number of observations	1587		1912	

➢ Interpretations of estimation results

1. There is a tendency for arable land utilization for rice cultivation to be reduced more by producers that have a great deal of farmland in small plots. These effects are larger for efficient producers.

For efficient rice farmers, the proportion of farm area that is undisposed or in micro plots of less than 10 are has the largest effect on arable land utilization for rice production; these effects gradually decline as the plots grow larger.

The effect is much smaller for inefficient producers.

More efficient rice producer tends to switch from rice grown on a small plot to other crops, and his land employed for rice cultivation is concentrated in relatively large-scale fields.

2. A certified farmer significantly reduces the arable land used for rice production. Furthermore, the more efficient a certified farmer is, the larger this effect is.

An *efficient* certified farmer reduces arable land utilization rate for rice production by 6.5%, while the extent of the reduction by *inefficient* certified farmers is only 3.1%

9.Concluding Remarks

- The negative effect of being certified farmer on arable land utilization for rice production may reflect the fact that cooperation in production adjustment for rice was a requirement at the stage of applying for certified farmers prior to 2009.
- However, productivity of rice production will decline as *efficient* certified farmers reduce the proportion of arable land used for rice production, which is the opposite of what was intended by policymakers.

- An agricultural system, such as certified farmer system, should be designed so that it might give incentives to *efficient* rice producers to expand rice cultivation, and *inefficient* producers to withdraw from rice cultivation and switch to other crops.