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Quality improvement and sustainable growth in Japanese agriculture

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ABSTRACT

As modern agricultural growth has been attained through increasing use of material input, it is discussed whether agricultural growth can be sustained in the long run within the limit of environmental tolerance. In order to investigate the possibility of the long-run growth, this study applies Aghion and Howitt's Schumpeterian growth model, and conducts empirical analyses using rice production panel data from eight regions in Japan for the period 1984 to 1999. Estimation of the translog cost function, which incorporates quality improvement effects, as well as the growth accounting estimation, reveals that the growth with quality improvement occurs, as the growth with increasing material input is stagnant. The quality-based innovation does not lead to increases in chemical input, implying the shift in innovation plays a key role in attaining sustainable development, which also explains a greater increase in pollution at the early stage of development and its slowing down. Sustainable growth can be attained through quality innovation even if environmental regulations are tightened.

JEL Classification code: Q16

Keywords: Innovation, Technological Change, Endogenous Growth, Japanese Agriculture

1. INTRODUCTION

As modern agricultural growth has been attained through increased use of material inputs, economists have discussed whether agricultural growth can be sustained in the long run within the limit of environmental tolerance. Using the economic growth model with an AK-type production function, Stokey (1998) shows that a positive economic growth rate cannot be sustained in the long run. In the AK model, where technological progress is generated by increasing use of physical capital, the amount of material inputs that generate pollution will also increase with output. Therefore, as an optimal intensity of pollution decreases, the growth rate of output becomes negative in the long run. In opposition to her paper, Aghion and Howitt (1998) argue that long-run growth is feasible through innovation to improve the quality of goods, using the Schumpeterian model of economic growth¹, which assumes that the source of the growth is incremental ‘intellectual capital’ used for increasing the quality of goods. Although their idea seems to be plausible with regard to the agriculture situation, it has been rarely tested in past literature.

The purpose of this study is to analyze whether sustainable growth in agriculture is feasible or not, by using the Aghion and Howitt’s model that is modified for problems existing within an agricultural sector². Then, this paper conducts an empirical analysis of Japanese rice production. This paper puts forward the hypothesis that the source of economic growth has shifted from quantity-based innovation to quality-based innovation, thus the growth can be maintained even

¹ Grimaud (1999) extends the Aghion-Howitt model to a decentralized economy case.

² This paper uses Aghion and Howitt’s (1998) definition of sustainable development, where current and future welfare is maximized under finiteness of resources, substitution of capital and natural resources, and existence of environmental costs of production and consumption.

after the growth ceases with increases in material input.

The Schumpeterian model implies pollution does not increase. In terms of agricultural production, the amount of chemical input, which negatively impacts on the environment, tends to increase rapidly during the earlier stage of development, and the rate of increase eventually declines (Figure 1). This change may indicate the possibility of a shift in the patterns of innovation and the potential for sustainable growth. Innovation in the Schumpeterian model is attained through a process of ‘creative destruction’; that is, new products of higher quality make old products obsolete. In terms of Japanese rice production, new varieties of rice with higher market value have replaced old varieties, and have driven them out of the market, thus that the technical growth seems to follow creative destruction (Figure 2). Consequently, innovation in quality improvement, has become an important factor for the sustainable development of agriculture, so for the purpose of analysis, the Schumpeterian model can be applied.

The next section shows the Schumpeterian model as in Aghion and Howitt (1998), applied to the agricultural situation. This is followed by an empirical analysis using Japanese rice production data. Section 3 explains the data collection methods, and Section 4 discusses the results of the estimation, followed by the conclusion in Section 5.

2. QUALITY-BASED GROWTH MODEL WITH POLLUTION

Suppose all individuals in the economy share the same linear preferences over an infinite time horizon and they consume a single product, c , say ‘food’:

$$W = \int_0^{\infty} e^{-\rho t} u(c(t), E(t)) dt, \quad (1)$$

where ρ is the subjective rate of time preference; $c(t)$ is the time path of consumption per head; and $E(t)$ is the aggregate indicator of the environmental quality, measured as actual quality level of

the environment minus its upper limit. Thus, $E < 0$. The upper limit of the environment would be realized only in a case that there is no production in the economy. The level of pollution, P , is assumed to be determined by the amount of material input, K_1 , including all intermediate inputs, such as seed, fertilizers, pesticides. Also, assume the amount of durable capital, K_2 , used for the production is assumed to be proportional to the amount of K_1 , thus that the aggregate capital, $K = K_1 + K_2$ and the area of farmland is fixed.

Let Z be the ‘intensity of pollution’, thus that $P(K(t), Z(t)) = K(t)(Z(t))^\gamma$. As a technology becomes more and more ‘clean,’ the parameter Z approaches zero. While Aghion and Howitt assume that that amount of pollution is positively related to an output level under a given technology, this paper supposes that it is proportional to a level of material input. The rate of changes in the environmental level E is represented by

$$\dot{E}(t) = -P(t) - \theta E(t) = -K(t)(Z(t))^\gamma - \theta E(t), \quad \gamma > 0. \quad (2)$$

Suppose the instantaneous utility function $u(c, E)$ is isoelastic in terms of c and E ,

$$u(c, E) = (c^{1-\varepsilon} - 1)/(1-\varepsilon) + [-\{(-E)^{1+\omega} - 1\}/(1+\omega)] \quad \text{with } \varepsilon > 0, \quad \omega > 0, \text{ so that}$$

$\partial u(c, E)/\partial c = c^{-\varepsilon}$ and $\partial u(c, E)/\partial E = (-E)^\omega$. The aggregate final good Y is processed from the intermediate goods x as follows:

$$Y(t) = A \int_0^1 B_i(t) (x(t))_i^\phi di, \quad 0 < \phi < 1, \quad (3)$$

where B_i is an indicator of the quality. The amount of factors of production for the good x is assumed to be unrelated to the quality level. Thus, the constant returns to scale production function of the intermediate good may be given by

$$x_i = K_i^\alpha L_i^{1-\alpha}, \quad 0 < \alpha < 1, \quad (4)$$

where L and K are the amount of labor and capital.

Aghion and Howitt (1998) show that the same quantity of each good is produced at the

optimum. Let B be the average quality level. Also, let n be population in the research and development sector, so that the population in the production sector is $1-n$, assuming total population L equals 1.

Suppose the output level declines as the parameter Z decreases. Then, the production function is

$$Y = K^\alpha \{(1-n)B\}^{1-\alpha} Z. \quad (5)$$

The rate of innovation to enhance the quality is determined by the number of researchers n and arrival rate of research outcomes η so that

$$\dot{B} = \sigma\eta nB. \quad (6)$$

Thus, this intellectual capital is produced by ‘clean technology,’ so that it does not emit pollution.

The problem is to maximize W subject to (2), (6), and $\dot{K}(t) = Y(t) - c(t)$, where L is the total population and n is the population in the research and development sector. Then, the Hamiltonian is

$$H = u(c, E) + \mu(\sigma\eta nB) + \zeta(-KZ^\gamma - \theta E) + \lambda[AK^{\alpha\phi}(1-n)^{(1-\alpha)\phi}BZ - c] \quad (7)$$

The first order conditions are $\partial H / \partial B = 0$ and $\partial H / \partial c = 0$. Thus,

$$\partial u / \partial c = c^{-\varepsilon} = \lambda, \quad c = \lambda^{-1/\varepsilon}, \quad \dot{c} = (-1/\varepsilon)\lambda^{-1/\varepsilon-1}\dot{\lambda}$$

$$\dot{c}/c = (-1/\varepsilon)(\dot{\lambda}/\lambda) \quad (8)$$

Also, since $\partial H / \partial Z = 0$,

$$-\zeta K\gamma Z^{\gamma-1} + \lambda AK^{\alpha\phi} B(1-n)^{(1-\alpha)\phi} = 0$$

$$\lambda = \frac{\gamma\zeta KZ^{\gamma-1}}{ABK^{\alpha\phi}(1-n)^{(1-\alpha)\phi}} = \frac{\gamma\zeta K^{1-\alpha\phi} Z^{\gamma-1}}{AB(1-n)^{(1-\alpha)\phi}}. \quad (9)$$

The Euler equations are $\partial H / \partial E = \rho\zeta - \dot{\zeta}$ and $\partial u / \partial E - \theta\zeta = \rho\zeta - \dot{\zeta}$.

From $\partial u / \partial E = (-E)^\omega$,

$$\dot{\zeta} = \rho\zeta - (-E^\omega) + \theta\zeta. \quad (10)$$

Also,

$$\begin{aligned} \partial H / \partial K = \rho\lambda - \dot{\lambda} &= \lambda\alpha\phi AK^{\alpha\phi-1}(1-n)^{(1-\alpha)\phi} BZ - \zeta Z^\gamma \\ &= \lambda\alpha\phi(Y/K) - \zeta Z^\gamma \end{aligned} \quad (11)$$

$$\dot{\lambda} / \lambda = \rho - \alpha(Y/K) + (\zeta / \lambda)Z^\gamma. \quad (12)$$

From (9),

$$\dot{\lambda} / \lambda = \rho - \alpha(Y/K) + \frac{AB(1-n)^{(1-\alpha)\phi} Z}{\gamma K^{1-\alpha\phi}}. \quad (13)$$

Substituting this into (8),

$$\begin{aligned} \dot{c} / c &= -\frac{1}{\varepsilon} \left[\rho - \frac{\alpha Y}{K} + \frac{AB(1-n)^{(1-\alpha)\phi} Z}{\gamma K^{1-\alpha\phi}} \right] \\ &= \frac{1}{\varepsilon} \left[\left(\frac{Y}{K} \right) \left(\frac{Z}{\gamma} + \alpha \right) - \rho \right]. \end{aligned} \quad (14)$$

As long as $(Y/K) > (\rho/\alpha)$, the growth rate of consumption decreases while maintaining a positive value, even when Z approaches zero. In an economy where Y is greater than K and the cost share of capital (α) is larger than the rate of interest (ρ), continuous growth is attainable through the improvement in quality of the products.

Aghion and Howitt (1998) maintain that strengthening environmental regulations will not reduce the growth rate of consumption, while Stokey (1998) shows that eventually the growth rate will become negative owing to the environmental regulations. Both appear to be extreme outcomes. According to the model in this paper, intensifying the regulations lead to a lower but positive growth rate.

Assuming Z is constant for the present, since $Y/K = AL^{(1-\alpha)\phi} Z(B/K^{1-\alpha\phi})$, the growth rate is positive, as long as the growth rate of B is faster than the growth rate of $K^{1-\alpha\phi}$. Since

$0 < (1 - \alpha\phi) < 1$, $K^{1-\alpha\phi}$ is likely to grow faster at a lower level of K , while it is likely to become slower. On the other hand, B keeps growing at a constant rate when n is constant. It implies that growth by increasing use of physical capital may occur earlier when marginal product of K is higher and eventually the innovation of quality improvement appear to be the major factor to maintain the economic growth.

3. DATA

For the estimation, this paper uses panel data of commercial farm households engaged in rice production, which exclude self-sufficient households. The annual data in eight districts of Japan, excluding *Hokkaido*³, for the period from 1984 to 1999 has been obtained from the *Survey on Production Cost of Rice, Wheat and Barley* published by Japan Ministry of Agriculture, Forestry and Fisheries (MAFF). The rice production is assumed to use four inputs: labor, land, chemical, and capital. Price of land is estimated as the rental costs per hectare of farmland, including those for farmers' own land. Labor wages are obtained by dividing the cost of labor by the total working hours. Following past literature of production analysis of Japanese agriculture, the coefficient of 0.8 is multiplied for female labor hours, in order to adjust the difference between male and female labor. Capital prices are computed by the Divisia index of the agricultural machinery and equipment, fuels, land improvement, water utilization and buildings. Prices for intermediate input are also estimated using the Divisia index of fertilizers, agricultural chemicals, seed, and miscellaneous materials. The prices of the inputs are obtained from the *Statistical*

³ *Hokkaido*, the northern island of Japan, is excluded from the estimation, since the average farm size and technological structure is considerably different from that of other regions in Japan, and the sample size for the region is small.

Survey of Prices in Rural Areas (MAFF). The amount of capital and intermediate input used for production are estimated by dividing the cost of the input by the prices.

The aggregate index for quality of rice is assumed to change as the proportion of rice varieties of different quality shifts. Also, one may postulate that the average price of an individual rice variety for the 1996-98 period represents the quality level for that variety, and it does not vary over the period of estimation. The quality index of each variety is computed from the average price for the 1996-98 period, using a ratio of the planting area of the variety as a weight, and standardized as the average of the initial values in all regions equals 1. The number of varieties used for the estimation is 183 for all regions. For varieties which prices are not available in the period 1996-98, prices of other varieties with the same level of “taste” and “appearance” have been used⁴.

4. ESTIMATION

The first part of this section estimates the total factor productivity (TFP) for the rice production in eight regions of Japan using the growth accounting method and collates together the estimated TFP with indices of the yield and the product quality. The growth accounting approach has an advantage in calculation of the productivity with a small sample, without causing the problem of degree of freedom. Average growth rates are obtained by regressing the logarithm of the variables on a linear trend. Contribution of improvement in the product quality to the TFP growth is estimated as a proportion of the annual growth rate of the quality indices to the annual growth rate of the TFP.

⁴ The data is obtained from *Suirikuto Mugirui Shorei Hinshu Tokusei Hyo* (in Japanese), Ministry of Agriculture, Forestry and Fisheries, Japan), in various issues.

Table 1 shows estimates for the TFP, the yield per hectare, the quality indices, and the contribution of quality improvement to the TFP growth in the eight regions: *Tohoku* (I), *Hokuriku* (II), *Kanto* (III), *Tokai* (IV), *Kinki* (V), *Chugoku* (VI), *Shikoku* (VII), and *Kyushu* (VIII). In the region I and the region II where the initial average costs are lower, that is productivity is higher, the initial levels of yield are higher. In these regions, the subsequent growth rate of yield is lower, while the growth rate of quality is higher. On the other hand, in the region V and the region VI, where the initial average costs are higher, the initial level of yield is lower, the growth rate of yield is higher, and the growth rate of quality is lower. It implies that in the earlier period productivity increases with yield, and eventually the quality begins to increase as the yield reaches a certain level. Notice that although the growth rate of yield in the region I and the region II turns to negative, the increases in quality have offset effects from decreases in yield so as to sustain a high TFP growth rate. . The results from the estimation suggest that there is no evidence of a decline in productivity growth. Furthermore, the contribution of the quality changes in total TFP growth accounts for more than 50 percent in the region I and the region II, and more than 30 percent in the all regions except the region IV, where initial yield is especially low. This supports the argument that quality improvement has become the major source of growth.

Table 2 shows the relationship between changes in the quality and the yield of rice using the panel data. The F-test for the restrictions of the pooled data model supports the fixed effect model against the pooled data model with 1 percent level of significance. The coefficient estimate of the yield in the fixed effect model is significant at the 1 percent level. Thus, there is a negative relationship between the yield and the quality of rice after eliminating the effects of the time trend.

Next, we investigate how quality-improving innovation affects demand for each factor of production, using a cost function with two kinds of technology parameters: technological changes

in quality improvement and ordinal technological changes, which do not take account of the effects of quality changes:

$$\begin{aligned} \ln C = & \alpha_0 + \sum_j^n \alpha_i \ln w_i + \gamma_Y \ln y + \gamma_Q \ln q + \delta_i t + \frac{1}{2} \gamma_{YY} (\ln y)^2 + \frac{1}{2} \gamma_{QQ} (\ln q)^2 + \frac{1}{2} \delta_{ii} t^2 \\ & + \frac{1}{2} \sum_i^n \sum_j^n \beta_{ij} \ln w_i \ln w_j + \sum_i^n \gamma_{iY} \ln w_j \ln y + \sum_i^n \gamma_{iQ} \ln w_j \ln q + \sum_i^n \delta_{ii} \ln w_j \cdot t \\ & + \gamma_{YQ} \ln y \ln q + \gamma_{Yt} \ln y \cdot t + \gamma_{Qt} \ln q \cdot t + \sum_i^R \phi_i D_i \end{aligned}$$

where C is the total cost; w is the price of input; y is the quantity of output; q is the quality of the output; t is the time trend; D is the dummy variable for regional fixed effects. The cost share equations are obtained by the shephard's Lemma, which includes lagged dependent variables in order to avoid the problem of serial correlation in errors:

$$S_i = \alpha_i + \sum_j^n \beta_{ij} \ln w_j + \gamma_{iY} \ln y + \gamma_{iQ} \ln q + \delta_{ii} t + \lambda S_i(-1)$$

where S is the cost share of factor and $S(-1)$ is the lagged variable for it. The short-run elasticities of the factor i with respect to the output and the quality of product are obtained by $\eta_{iY} = \gamma_{iY} / S_i^* + 1$ and $\eta_{iQ} = \gamma_{iQ} / S_i^* + 1$, where S_i^* is the fitted values of the factor share i (Oniki, 2000). Here, the effects of output and quality are evaluated by $\eta_{iY} - 1$ and $\eta_{iQ} - 1$. Thus, a positive value means that the share of the factor i increases as the quantity y or the quality q increases, holding the other variables constant, while a negative value means the share decreases. The bias of technical change under constant quality is estimated by δ_{ii} / S_i^* . While the Durbin-Watson tests detect significant autocorrelation in all share equations without the lagged share variables, no significant autocorrelations are detected in equations with first-order lagged dependent variables. Symmetry and homotheticity conditions for the parameters of factor prices are imposed *a priori*. According to the estimated price elasticities, all factor demands are negatively sloped (Table 3.2). The monotonicity condition is satisfied since the fitted factor

shares are positive.

Table 3.1 shows effects of changes in the quantity and the quality of output, as well as the technical change biases. Regarding the share for the intermediate input (*e.g.*, fertilizers, pesticides), the quality effects are not significantly different from zero, while the output effects and the technological change biases are both significant at the 10 percent level. It suggests that improvement in quality does not increase the demand for the intermediate inputs.

In addition, in order to check whether the amount of chemical per output does not increase in a long run, the time trend of the variable is examined. The amounts of fertilizer, pesticides and other agricultural chemical are aggregated into the Divisia index for chemical input. The two types of regressions are conducted using output that is adjusted to the quality change and output that is not adjusted to it. While the estimation using output data that is not adjusted to the quality detects a positive trend, that adjusted to the quality shows a negative, although the estimates are not statistically significant (Table 4). Therefore, if quality improvement is taken into account, amount of chemical does not increase and may have negative trend.

5. CONCLUSION

This study has applied the Schumpeterian growth model for the problem of agricultural growth, and conducted empirical analysis regarding Japanese rice production. It reveals that innovation to improve quality of rice occurs, as growth to raise the yield by increasing the amount of material input decelerates. In other words, quality innovation is induced by stagnation of the material-based innovation; thus it may be regarded as a sort of induced innovation. In the past,

technology to increase the yield developed, as returns to expanding land areas diminish⁵. Now similarly, quality innovation is accelerated as the improvement in yield approaches the limit.

The analysis also indicates that the quality innovation in the rice production does not increase the demand for intermediate input, such as fertilizers and pesticides. Also, since quality innovation occurs behind the material innovation, pollution due to the material input increases rapidly at the early stage of development, and its speed gradually declines, as confirmed in past empirical studies on the environmental Kuznets curve⁶. Therefore, sustainable growth could be continued if quality improvement is maintained in the long run.

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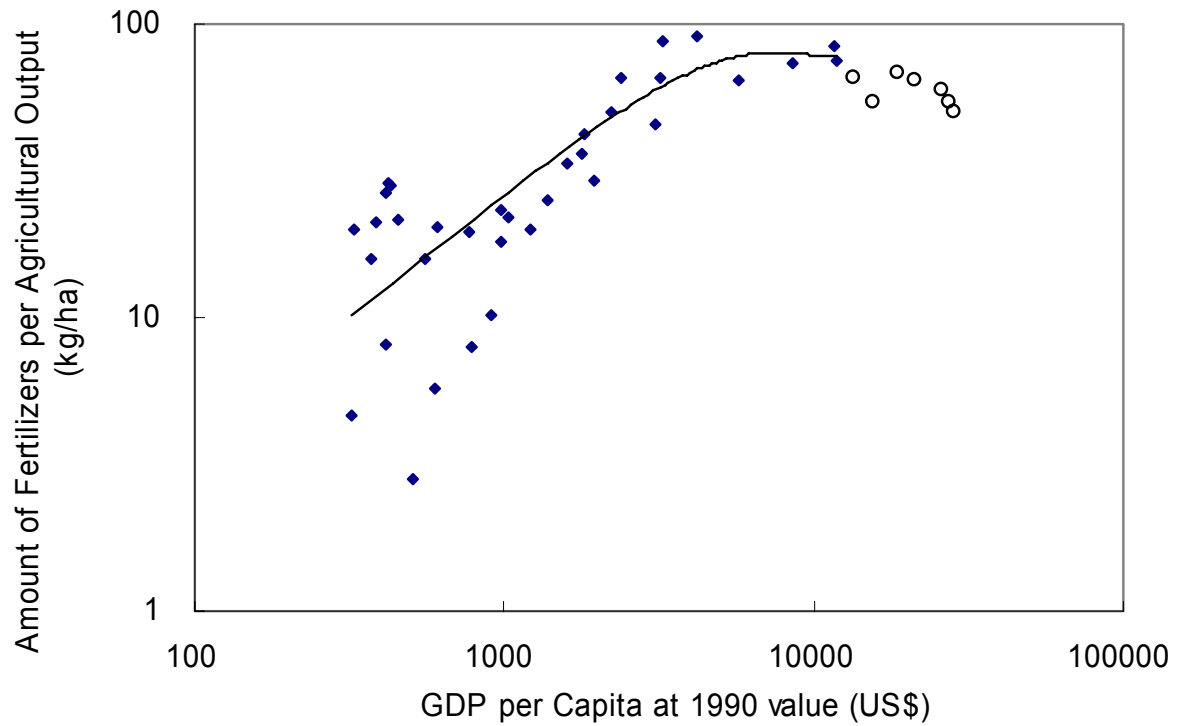
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⁶ For example, Grossman and Kruger, 1992; Seldan and Song, 1994; Taskin and Zaim, 2000.

TABLES AND FIGURES



Note: The amount of fertilizers is sum of nitrogen, phosphorus, and potassium.

The Japanese data are indicated by small round marks ().

Data: International Financial Statistics, World Economic Outlook, and FAO-Stat.

Data of Japan, Korea, Thailand, Indonesia, Malaysia, and the Philippines in 1970, 1975, 1980, 1985, 1990, and 1998. The countries whose time-series data are not available and those for socialist economies are excluded.

Figure 1. Amount of Fertilizers per Agricultural Output and Real GDP per capita in Selected Asian Countries.

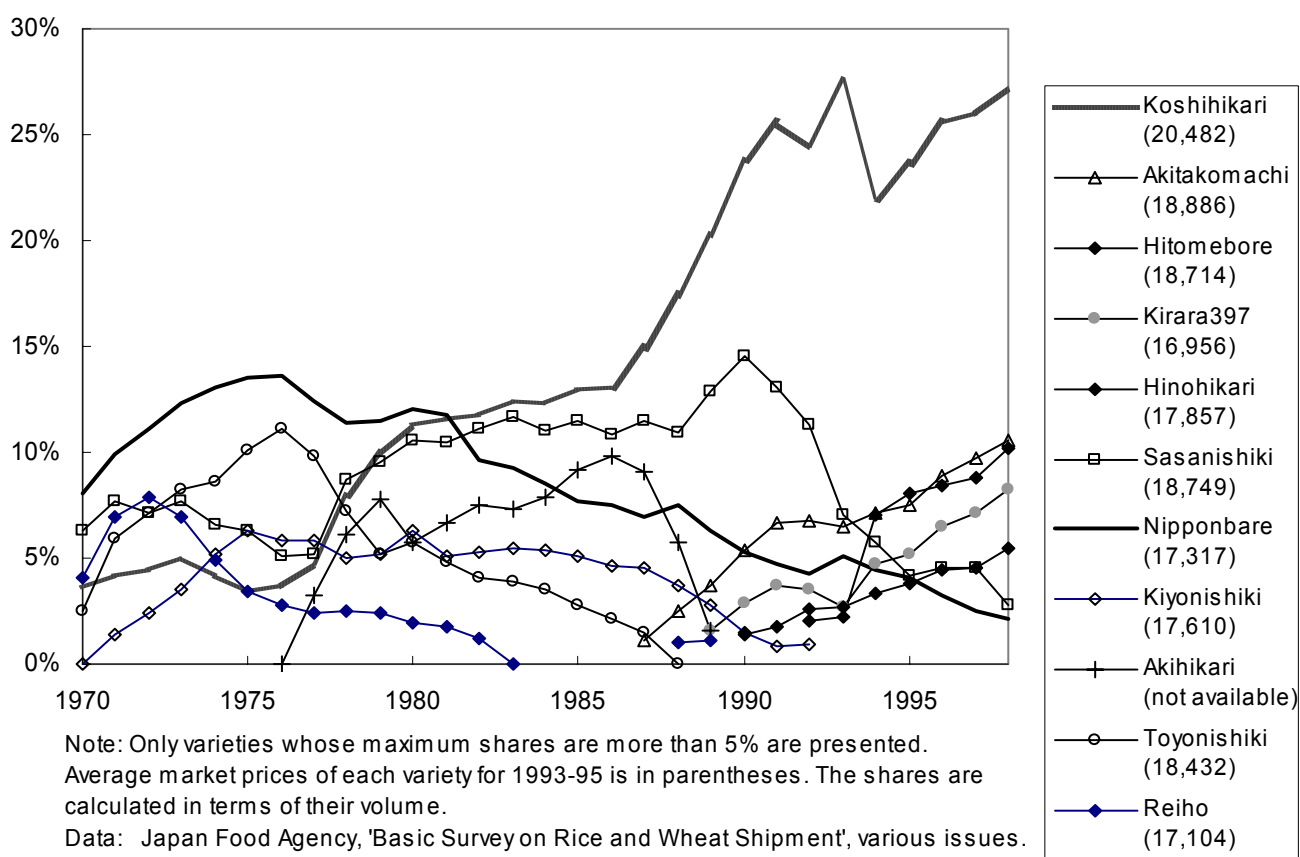


Figure 2. Share of Rice Shipment, by Varieties, 1970-95

Table 1 Growth Accounting and the Related Variables of the Japanese Rice Production, 1984-99

	Region**							
	I	II	III	IV	V	VI	VII	VIII
Initial value of average cost (1984)	0.93	0.95	0.94	1.09	1.23	1.19	1.12	1.00
Initial value of yield (1984-86)	1.09	1.04	0.95	0.93	0.95	0.96	0.97	0.95
Annual growth rate of TFP*	1.09%	0.95%	0.78%	0.78%	1.45%	0.69%	0.63%	1.22%
Annual growth rate of yield	-0.39%	-0.40%	0.35%	0.13%	0.30%	0.24%	-0.13%	0.68%
Annual growth rate of quality of rice	0.59%	0.51%	0.31%	0.27%	0.20%	0.31%	0.38%	0.38%

*Adjusted by the quality changes

**I: Tohoku, II: Hokuriku, III: Kanto, IV: Tokai, V: Kinki, VI: Chugoku, VII: Shikoku, VIII: Kyushu

Note: The initial values are standardized to 1, using the average values for all regions in the initial period of estimation.

The initial values of yield are obtained by averaging values of first three periods to mitigate variation caused by weather.

Table 2 Panel Data Analysis on the Quality Index

	Model			
	Pooled data		Fixed Effect	
Constant	0.8078	(13.073)	n/a	
Yield	0.0036	(2.892)	-0.0002	(-5.664)
Trend	0.0049	(4.535)	0.0038	(22.003)

Note: The values in the parantheses show t-statistic computed by the heteroscedastic-robust standard errors

Table 3.2 Price Elasticity of Demand

i \ j	Labor	S.E.	Land	S.E.	Intermediate	S.E.	Capital
Labor	-0.560	0.024	0.051	0.028	0.110	0.007	0.399
Land	0.103	0.057	-0.484	0.134	0.182	0.019	0.199
Intermediate	0.270	0.018	0.219	0.023	-0.374	0.166	-0.115
Capital	0.324		0.079		-0.038		-0.365

Note: S.E.: Standard errors estimated by $SE(\epsilon_{ij})/S_i$

Table 3.1 Output Effects, Quality Effects, and Technical Change Biases

	Labor	S.E.	Land	S.E.	Intermediate	S.E.	Capital
Output effect	-0.146	0.030	0.402	0.082	0.040	0.018	-0.055
Quality effect	-0.179	0.049	0.140	0.136	-0.102	0.067	0.123
Technical bias	-0.415	0.135	0.005	0.005	0.005	0.002	0.333

Note: S.E.: Standard errors estimated by $SE(y_{iy})/S_i$, $SE(y_{iQ})/S_i$, $SE(\delta_{iy})/S_i$

Table 4 Panel Data Analysis on Chemical Inputs per Output

	Dependent variable: Log of chemical input per output			
	Adjusted to output quality		Not adjusted to output quality	
Trend	-0.00092	(-0.240)	0.00293	(0.722)
Constant	9.90906	(0.034)	9.90692	(276.531)

Note: The values in the parantheses show t-statistic computed by the heteroscedastic-robust standard errors