[*Jpn. J. Rural Econ.* Vol. 15, pp. 1–18, 2013]

Optimal Behavior of Rice Farmers in the Imperfectly Competitive Land Lease Market in Japan: With a Focus on Transaction Costs and Uncertain Returns on Land Lease Investment

Hitoshi Kusakari* and Satoshi Nakagawa†

In the process of drawing up contracts, farmers must pay some transaction costs, including the cost for searching for appropriate farmlands. In addition, farmers tend to postpone making contracts because of their anxiety about uncertain returns on land lease investment in spite of present profitability. The objective of this study is to judge whether transaction cost and uncertain returns work as restrictions on the number of land lease contracts in Japan. This study assumes that the previous papers associated with this context overestimated the number of the contracts because they ignored the effects of two obstacles as a result of their preconception of the competitive market framework. The originality of this study is to prove the previous overestimation from theoretical and empirical viewpoints, and to estimate the transaction cost and the option value coefficients as an index of uncertain returns by applying real option theory. The main outcomes of this study are as follows: First, the study makes it clear theoretically that the perfectly competitive land lease market assumption adopted by the previous papers leads to the overvaluation of the number of land lease contracts when market competitiveness is imperfect. Second, the study proves empirically that the land lease markets of rice farming are imperfectly competitive according to the significant estimation results of the transaction costs and the option value coefficients. Third, from the estimation results of the study, the estimate of the transaction costs in the former period from 1981 to 1992 was relatively larger than the estimate in the latter period from 1995 to 2002; on the other hand, the estimate of option value coefficient in the former period was relatively smaller than the estimate in the latter period. These results imply that each of the two obstacles restricts the number of land lease contracts at different periods. The empirical results of this study strongly suggest that government policy to mitigate both transaction costs and a degree of uncertainty of returns on land lease investment is effective in accelerating farmland lease contracts in rice farming in Japan.

Key words: farmland lease contract, transaction cost, uncertain return, real option theory, imperfectly competitive market.

1. Introduction

The improvement of the agricultural structure by expanding farm size has been one of the most important issues in agricultural policy in Japan since the enactment of the Agricultural Basic Law in 1961. In the late 1950s, the number of farm households and the population mainly engaged in farming, which had been considered constant since the Meiji Era, excluding a couple of years after World War II, began to decrease. The reduction of heavy population pressure on

*Kobe University
†Hyogo Prefectural Union of Agricultural Co-operatives
This refereed paper is based on *Journal of Rural Economics* Volume 83 No. 1, which was awarded the 2012 Journal Article Prize of the Agricultural Economics Society of Japan.

rural areas suggested that farm size could be expanded. This is the reason why the agricultural policy at the core of the Agricultural Basic Law tried to improve small-scale farming and small farmland holding. Although almost half a century has passed since the establishment of the Agricultural Basic Law, Japanese agriculture has been weakening. Improvement in the agricultural structure has been stagnant and the agricultural labor force has been shrinking due to increases in the number of part-time farmers and the age of farmers. Structural improvement, as yet to be accomplished, is still longed for as an effective measure to stem the deterioration of Japanese agriculture, but the current situation indicates that there is little time left in which to improve.[1)]

The concept of farmland mobility, the keystone of structural improvement, has produced many empirical studies. These studies have mainly tested Kajii's hypothesis in the context of farmland lease contracts.[2)] This research into farmland mobility in the lease market, has not obtained realistic results because of the overevaluation of the number of farmland lease contracts, resulting from the implicit assumption that the farmland lease market was perfectly competitive.

This paper argues that the assumption that the farmland lease market is perfectly competitive is the cause of the failure of previous research. Two factors omitted by previous studies are focused on. One is transaction costs. Transaction costs include, for example, search cost for the lease in examining land quantity and quality, coordination cost with neighboring farmers and procedural costs in exchanging contracts. The other is uncertainty of future returns. Kajii's hypothesis sees farmland mobility in the lease market as related to present profitability. However, in the case where future returns are uncertain, it is more likely that a farmer chooses to make no lease contract and to maintain the status quo, even when Kajii's hypothesis is satisfied. Accordingly, a farmer may not make a lease contract because of anxiety about the future, even if leasing the farmland would be profitable. If the farmland lease market is imperfectly competitive, due to transaction costs and uncertainty, farmland lease contracts that would be made in a perfectly competitive market may not be actually made. In short, the previous studies, which assumed a perfectly competitive market, paid little attention to the following facts: First, a farmer decides carefully to make a farmland lease contract by considering the current and future conditions. Second, market mechanisms do not work effectively in the allocation of farmland because of imperfect competitiveness.

The objective of this paper is to theoretically and empirically examine why farmers made fewer farmland lease contracts than previous studies predicted, by analyzing farmers' behavior in an imperfectly competitive farmland lease market. In the literature on farmland mobility in the lease market, Kusakari [17] and Fujie [5] analyzed the problem theoretically using a framework that explicitly included transaction costs. Takahashi's [31] study indirectly supported the occurrence of transaction costs in the farmland lease market by using proxy variables. However, Arimoto and Nakajima [1] stated that it was almost practically impossible to estimate the amount of transaction costs directly. No empirical analyses have succeeded in estimating the amount of transaction costs empirically. At the same time, no research has examined theoretically or empirically how uncertain returns affect farmland lease behavior.

This paper analyzes farmers' farmland lease behavior theoretically and empirically using a framework which embeds transaction costs and uncertainty of returns. First, three criteria for making farmland lease contracts are defined: (1) a criterion of present profitability in a perfectly competitive market (including Kajii's hypothesis), (2) a criterion of net present value (NPV) with transaction cost, and (3) a criterion taking account of transaction costs and uncertain returns. Second, because the concept of an imperfectly competitive market includes a perfectly competitive one in special cases, this paper shows theoretically that lease contracts are easiest to make under criterion (1) and hardest to make under criterion (3). Third, from an empirical analysis based on criterion (3), it is argued that the farmland lease market is imperfectly competitive; therefore, the transaction costs and uncertainty of returns have prevented farmland lease. Fourth, by comparing the empirical results based on Kajii's hypothesis, specifically the case of criterion (1) and criterion (3), those theoretical relations are investigated. As stated above, the aims of this paper are to explore theoretically the relation between the

characteristics of the farmland lease market and the three criteria for making farmland lease contracts; then, to prove how transaction costs and uncertain returns affect farmers' behavior in the lease market by direct estimation of the transaction costs and the measure of uncertain returns.

Section 2 explains the historical circumstances of farmland mobility in Japan and reviews related studies. Section 3 illustrates the analytical framework and argues that the application of real option theory by Dixit and Pindyck [4] is an effective tool for analysis. Section 4 presents the estimation model and data for empirical analysis and section 5 discusses the estimation results. Finally, in section 6, a number of conclusions are made.

2. Review of Farmland Mobility in Japan

While agricultural policy based on the Agricultural Basic Law sought the improvement of the agricultural structure, a sharp rise in land price during the period of high economic growth spread to farmland in the suburbs. As is generally known, some farmers in the suburbs sold their farmland for housing and industrial uses and looked for alternatives in neighboring rural areas. As a result, an increase in farmland price extended gradually outward. Because of this, transfer of ownership of farmland became difficult, and the government needed to promote structural improvement through tenancy. However, the Agricultural Land Law carefully protected cultivation rights of tenant farmers and impeded the supply of farmland to the lease market. Under the circumstances, the government established the Agricultural Land Use Promotion Project, in amending the Law concerning Establishment of Agricultural Promotion Areas in 1975, which opened the way for farmland lease contraction by bypassing the restriction of the Agricultural Land Law. The government set up a new scheme for farmland lease contracts through "use rights" in which lease relationships were automatically dissolved on the expiration dates of the lease contracts. The Agricultural Land Use Promotion Project was separated from the Law concerning Establishment of Agricultural Promotion Areas and was enhanced in the Agricultural Land Use Promotion Law in 1980.[3)]

At that time, the presentation of Kajii's hypothesis [13] encouraged many empirical studies on farmland mobility, which focused on productivity differentials between size classes of planted areas in rice farming. Kajii's hypothesis [13] led Marxian economists to test whether productivity differentials were a factor in accelerating the polarization of rice farmers, as well as leading modern economists to test scale economies in rice cropping.[4)] However, many of those using Kajii's hypothesis did not sufficiently problematize the underlying assumptions of the hypothesis, including the image of the farmland lease market presumed in the hypothesis. In other words, the studies did not recognize sufficiently that Kajii's hypothesis implicitly assumed efficient allocation of farmland in a perfectly competitive lease market. In this regard, Shogenji and Nakashima [27] argue that the image of farmland lease market should be improved both theoretically and empirically. Kusakari [17] noted that there was some doubt over whether the productivity differentials among size classes in rice farming could increase farmland mobility because the differentials had been observed for more than 20 years. Indeed, he demonstrated theoretically that the differentials did not work as an incentive to increase farmland mobility due to the existence of transaction cost. Kusakari [18] also mentions that the logic of Kajii's hypothesis was reversed because productivity differentials were not an incentive to increase farmland mobility but were rather evidence of the immobility of the market. This reversion might be caused by focusing only on rice income and neglecting transaction costs. Hara [8] also pointed out critical shortcomings in Kajii's hypothesis, notably, the fact that large-size and small-size farms had existed together for a long time. Since the concept of imperfectly competitive market includes a competitive one in particular cases, this paper verifies whether the farmland lease market is perfectly competitive or not by using a framework of imperfect competition.[5)]

3. Analytical Framework

1) Transaction costs and uncertainty in farmland lease

A farmer wishing to rent land does so with stochastic search processes, since the farmer has to look for land within commuting distance. For this reason, the search process for farmland entails costs even for farmers wishing to make leases. The search cost amount for a borrower

is decided mainly by the size of the farmland area to be leased, the existence of lenders' reservation demand, and so on. Since a farmer meets a limit when expanding farm size through making farmland lease contracts with his/her neighbors, the more he/she expands the farm size, the wider the search area becomes.[6] Consequently, an increase in the area a farmer wants to borrow raises the search cost. An increase in lenders' reservation demand results in the reduction of lease land supply which also subsequently makes search costs high. This reservation demand is determined by lenders' expectations of farmland conversion, holding cost of farmland (e.g., assessed values of fixed assets, etc.), and so on. In addition, as is often the case in Japan, a farmer cultivates fragmented parcels of paddy field. Because of this, almost all borrowers should make efforts to cooperate with neighboring farmers for smooth utilization of their borrowed parcels. This externality, specific to the farmland lease market in Japan, is also a factor generating transaction costs related to coordination. Hence, the transaction costs in making a farmland lease contract consist of search cost, coordination cost and procedure cost.

Next, uncertainty also decreases the number of farmland lease contracts. In previous studies which have assumed a perfectly competitive farmland lease market, borrowers' decisions have been judged only in relation to present profitability. Even if the current conditions for making a contract are favorable, there is still room for a borrower not to make a contract due to his/her future expectations. Consequently, if there is uncertainty within the farmland lease market, a farmer may not make lease contracts even when Kajii's hypothesis is satisfied.

2) Farmland lease behavior and real option theory

Transaction costs and uncertainty are important factors generating an imperfectly competitive market. As mentioned before, Kusakari [17] and Fujie [5] analyzed the farmland lease market theoretically using a framework explicitly taking account of transaction costs, and Takahashi [31] analyzed empirically the occurrence of transaction costs implicitly using proxy variables. However, no empirical analyses have estimated the amount of the transaction costs themselves, and no theoretical or empirical studies have analyzed the effect of uncertainty of returns on farmers' behavior in the lease market. Transaction costs and uncertainty are undoubtedly the main points to consider when analyzing the characteristics and functions of the farmland lease market. In this paper, the relation between the characteristics and functions of the market and the three criteria for making farmland lease contracts are examined theoretically; then, transaction costs and the measure of the uncertainty of returns are estimated directly from their effects on the number of farmland lease contracts. At that time, borrowers' decisions to make farmland lease contracts are regarded as their investments in farmland lease. Real option theory is applied to these investments in order to estimate transaction costs and the measure of the uncertainty of returns.

Borrowers' investments entail transaction costs as sunk costs. In addition, contract length for farmland leases are generally several years long. Difficulty in the early termination of contracts and the cancellation of contracts before the terms have finished, makes returns on leases uncertain. With regard to uncertain future returns and transaction costs, borrowers can be better off postponing making lease contracts because of their expectations of changes in future returns. Hence, the existence of transaction costs and uncertainty makes the borrowers keep the status quo. Accordingly, in analyzing farmers' behavior in the farmland lease market, one must take into account transaction costs and the uncertainty of returns. The three criteria, (1) the criterion of present profitability in a perfectly competitive market (including Kajii's hypothesis), (2) the criterion of NPV with transaction cost, and (3) the criterion taking account of transaction costs and uncertain returns (i.e., the criterion based on real option theory), are presented below. In this paper, the presentation of real option theory is based on Dixit and Pindyck [4].[7]

Denoting a borrowers' profit per year from a farmland lease (i.e., a return from a farmland lease minus the rent) as R, (1) the criterion for making a lease contract in a perfectly competitive market is[8]

$$R \geq 0 \tag{1}$$

Denoting transaction costs as $T(T>0)$, (2) the criterion of NPV with transaction costs is $V(R) - T \geq 0$, where $V(R)$ is NPV of total profit (sum of NPV of each annual profit) from a farmland lease. If an annual profit R is constant

in every year and a discount rate is denoted as ρ, then $V(R)=R/\rho$.[9] When a farmer expects an increase in his/her profit, he/she wants to make a contract; then, the criterion for making the contract without uncertainty is

$$V(R)-T=\frac{R}{\rho}-T\geq 0 \qquad (2)$$

(3) The criterion taking account of transaction costs and uncertain returns is based on real option theory. In this theory, an investor (i.e., a borrower farmer) is regarded as an economic agent with a right to invest anytime he/she wants; therefore, the investor has the right to decide whether to make the investment immediately or to put it off.[10] "Making an investment at present" is understood as "exercising an option to invest." However, because of transaction costs and uncertain future returns after exercising an investment option, it becomes valuable for an investor not to exercise an investment option but to retain a right to invest anytime he/she wants. This value is referred to as an "option value."

In criteria (1) and (2), without consideration of uncertainty, shown in inequations (1) and (2), a borrower farmer has to decide whether (a) to make a farmland lease contract at present or (b) never to make the contract in the future. Although the criteria (1) and (2) differ in their definition between a present profitability as in inequation (1) and the NPV of profits in inequation (2), both criteria compel the borrower to judge immediately whether to make a contract. The two criteria initially exclude the option of postponing making a contract. It would be better to add an option (c) which relates to putting off making a contract with the expectation of changes in the future returns of options (a) and (b). The value arising from the postponement of making a contract is the option value.

Letting $F(R)$ denote the option value, the criterion for making a contract based on real option theory is that NPV of total profit from a farmland lease $V(R)$ is greater than the sum of the transaction costs T and the option value $F(R)$. Accordingly, in addition to the transaction cost, if uncertainty exists in a borrower's return, inequations (1) and (2) should be modified into

$$V(R)-T=\frac{R}{\rho}-T\geq F(R) \qquad (3)$$

When inequation (3) is not satisfied, the borrower puts off making a contract.

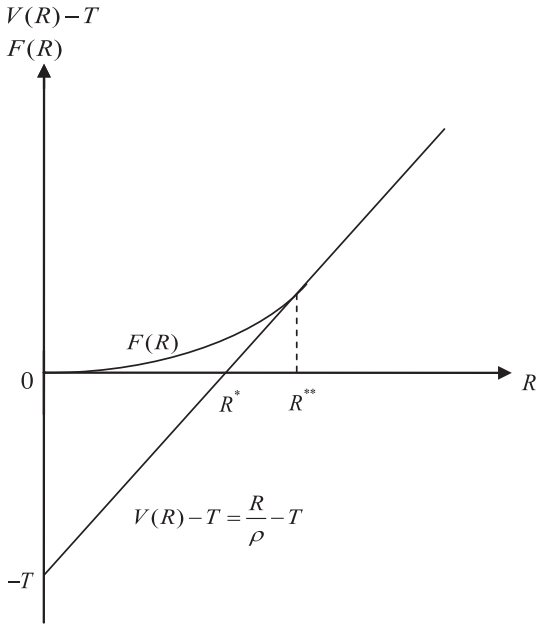

Figure 1. Option value and profits from a farmland lease

Summing up the discussion above, as the criterion changes from (1) to (3), the assumption of the farmland lease market becomes more relaxed and the criterion for making the contract becomes more complex. Instead of profit R in inequation (1), letting R_K denote the difference between surplus of a large-size farm and income of a small-size farm, then Kajii's hypothesis is written as

$$R_K\geq 0 \qquad (1)'$$

The surplus is defined as the difference between revenue and total cost in Marxian economics. In this case, the total cost consists of material cost and labor cost for family members.

3) Specification of the option value

This subsection specifies the option value $F(R)$ and analyzes the effects of transaction costs and uncertainty of returns on $F(R)$. Assuming that profit R follows a geometric Brownian motion with drift,[11] uncertainty of returns can be represented as

$$dR=\mu R dt+\sigma R dz \qquad (4)$$

where μ is the drift coefficient, σ is the standard deviation of the returns, and z is the standard Brownian motion. Using Ito's lemma to specify the option value, $F(R)$ is obtained as

$$F(R) = BR^{\beta} \tag{5}$$

In equation (5), B is a positive constant, and

$$\beta = \frac{1}{2} - \frac{\rho - \delta}{\sigma^2} + \sqrt{\left(\frac{\rho - \delta}{\sigma^2} - \frac{1}{2}\right)^2 + \frac{2\rho}{\sigma^2}} > 1 \tag{6}$$

where $\delta = \rho - \mu > 0$.

Figure 1 depicts the relations between NPV of total profit $V(R)$, transaction costs T, and option value $F(R)$. R^* and R^{**} in Figure 1 are the critical values in (2) and (3), respectively. Therefore, $V(R^*) - T = 0$ and $V(R^{**}) - T = F(R^{**})$.

As shown in Figure 1, if $R^{**} > R \geq R^*$, inequality (2) is satisfied but inequality (3) is not. Taking into consideration the uncertainty of future returns, a borrower should postpone making a contract in the interval from R^* to R^{**} under criterion (3); otherwise, he/she should make a contract under criterion (2). The option value resultant from uncertainty makes the decision relating to farmland leasing complex. In the remaining intervals of $R^{**} > R \geq R^*$, $R \geq R^{**}$ and $R^* > R$, the borrower will be better off by making a contract at present, or by never making a contract, respectively. As the above relations are fulfilled, the following two conditions should be satisfied at $R = R^{**}$.

$$F(R^{**}) = \frac{R^{**}}{\rho} - T \tag{7}$$

(value-matching condition)

$$F'(R^{**}) = \frac{\partial F(R^{**})}{\partial R} = \frac{1}{\rho} \tag{8}$$

(smooth pasting condition)

From equations (5), (7) and (8), equation (9) is defined when $\beta > 1$ and $R = R^{**}$.

$$R^{**} = \frac{\beta}{\beta - 1}\rho T \rightleftarrows V(R^{**}) = \frac{\beta}{\beta - 1}T > T \tag{9}$$

Then, from inequation (3) and equation (9), the option value is written as

$$F(R^{**}) = V(R^{**}) - T = \left(\frac{\beta}{\beta - 1} - 1\right)T > 0 \tag{10}$$

By setting $\beta/(\beta - 1) = \alpha$ in inequation (10), it is possible to derive the equation $F(R^{**}) = (\alpha - 1)T$ where α is the option value coefficient with $\alpha > 1$ because $\beta > 1$. The option value coefficient α is the parameter representing the effect of the uncertainty of returns on a farmland lease. When α goes down to 1, the option value goes down to 0. Furthermore, $\partial\alpha/\partial\beta < 0$ and $\partial\alpha/\partial\sigma > 0$ are satisfied as $\beta/(\beta - 1) = \alpha$ due to inequation (6). The above relation implies that a rise in the standard deviation of profit σ from a growth of uncertainty increases the option value coefficient α.

The above theoretical model implies the following: First, from $V(R^{**}) > T$ in equation (9), the relation $V(R^{**}) > V(R^*) = T$ is satisfied when $\partial V/\partial R > 0$. Hence, making a farmland lease contract under uncertainty requires a larger profit R^{**} than under conditions of certainty. This shows that, as illustrated in Figure 1, even if the NPV of total profit from a farmland lease exceeds the transaction costs corresponding to criterion (2), the borrower does not necessarily make the contract under uncertainty as under the criterion (3). Second, both increases in uncertainty and transaction costs raise the option value $F(R^{**})$ and the critical value of making the contract R^{**}. This is verified from the formulas relating to the option value, $F(R^{**}) = (\alpha - 1)T$ from equation (10), and of the critical value of making the contract, $R^{**} = \rho\alpha T$ from equation (9). This indicates that a growth in uncertainty and transaction costs tends to make the borrower put off making a contract.

4. Empirical Analysis

1) Estimation method

This paper specifies borrowers' behavior in an imperfectly competitive farmland lease market and estimates the amount of the transaction costs and the option value coefficient as a measure of the uncertainty. For this purpose, the model developed by Wossink and Gardebroek [33] is applied to the lease market for rice farmers in Japan. Because the uncertainty of returns on rice farming depends heavily on rice price in Japan, the estimation period is divided into two periods. These two periods display different overall trends in rice price.

Substituting $\beta/(\beta - 1) = \alpha$ into equation (9), the optimal conditions for a borrower in an imperfectly competitive market are as follows.

$$V_i(R) = \alpha T_i \tag{11}$$

$$V_i(R) = T_i \tag{12}$$

If equations (11) and (12) are satisfied, a borrower is indifferent in regards to making farmland lease contracts at present or keeping the

Table 1. The estimation results

	Period from 1981 to 1992 (the former period)		Period from 1995 to 2002 (the latter period)	
	Estimate	Statistic	Estimate	Statistic
T	67,822**	(2.902)	34,707*	(2.270)
α	2.1754**	(7.690)	3.2022**	(3.653)
λ	−0.4188	(−0.426)	−0.2990	(−0.503)
σ_u	36,961**	(17,321)	30,065**	(10,466)
σ_v	37,411**	(8,710)	30,668**	(7,107)
	Log likelihood: −1,184		Log likelihood: −793	

Note: 1) ** and * indicate significant differences from zero at 1% and 5% levels, respectively.
2) Statistics in parenthesis are t-values for T, α and λ, and asymptotic standard errors for σ_u and σ_v, respectively.

status quo (i.e., postponing making the contract). Equation (11) is the optimal condition for borrower i when considering the option value, and equation (12) represents the optimal condition without the option value.

Setting $T_i = T + v_i$ and assuming $v_i \sim N(0, \sigma_v^2)$, equations (11) and (12) are, respectively, transformed into

$$V_i(R) = \alpha T + u_i \tag{13}$$

$$V_i(R) = T + v_i \tag{14}$$

where u_i follows $N(0, \sigma_u^2)$ in equation (13). Assuming also a borrower considering the option value is observed with probability p, and a borrower not considering the option value is with probability $(1-p)$, the lease behavior of these farmers can be estimated by a switching regime model; therefore, a likelihood function for the lease behavior is specified as in equation (15) by using a standard switching regime model (see: Wossink and Gardebroek [33]). The parameters are estimated iteratively by maximizing the likelihood in equation (15) by means of the Davidson-Fletcher-Powell algorithm.[12)]

$$L = \prod_{i=1}^{S} [\psi(\lambda) f_i^1 + (1 - \psi(\lambda)) f_i^2] \quad (\psi(\lambda) = p) \tag{15}$$

where $f_i^1 = \frac{1}{\sigma_u} \phi\left(\frac{X_1}{\sigma_u}\right)$, $f_i^2 = \frac{1}{\sigma_v} \phi\left(\frac{X_2}{\sigma_v}\right)$,

$X_1 = \sum_{k=1}^{n} \left(\frac{R_i}{(1+\rho)^{k-1}}\right) - \alpha T$, and $X_2 = \sum_{k=1}^{n} \left(\frac{R_i}{(1+\rho)^{k-1}}\right) - T$.

In these equations, $R_i = MVP_i - w_i$, s is the number of samples, $\phi(\bullet)$ is a standard normal density function, $\psi(\bullet)$ is a standard normal distribution function, MVP is the marginal value product of farmland, w is rent, ρ is discount rate, and n is contract term length. To be consistent with the assumption that $\lambda \sim N(0, 1)$, probability p, represented in equation (15) as $\psi(\lambda) = p$, is put between 0 and 1. The estimation parameters in equation (15) are α, T, λ, σ_u and σ_v. $\alpha > 1$ is theoretically expected when a rice farmer recognizes the option value.

2) Estimation data

The data sources for this study are "Production cost by size of paddy field rice planted area" in *Kome Oyobi Mugirui no Seisanhi* (*Production Cost of Rice, Wheat and Barley*) by the Ministry of Agriculture, Forestry and Fisheries (MAFF), and "Area by duration of use rights (rights for lease)" in *Nochi no Ido to Tenyo* (*Transfer and Change of Agricultural Land*) by MAFF. Data from the farms divided into eight size classes (0.5–1.0 ha, 1.0–1.5 ha, 1.5–2.0 ha, 2.0–2.5 ha, 2.5–3.0 ha, 3.0–4.0 ha, 4.0–5.0 ha, and 5.0 ha and over) for all Japan (excluding Hokkaido and Okinawa) in two periods from 1981 to 1992 and from 1995 to 2002, were used in this study. Marginal value product (MVP) of farmland was estimated by size class in each year from an estimation of the translog variable profit function.[13)] The rent w was derived from the average of actual land rents per 10 a in size classes of 2.0 ha and over in *Production Cost of Rice, Wheat and Barley*.[14)] The contract length n was seven years. This was obtained from a simple average of the average contract length in each year. The average contract length in each year

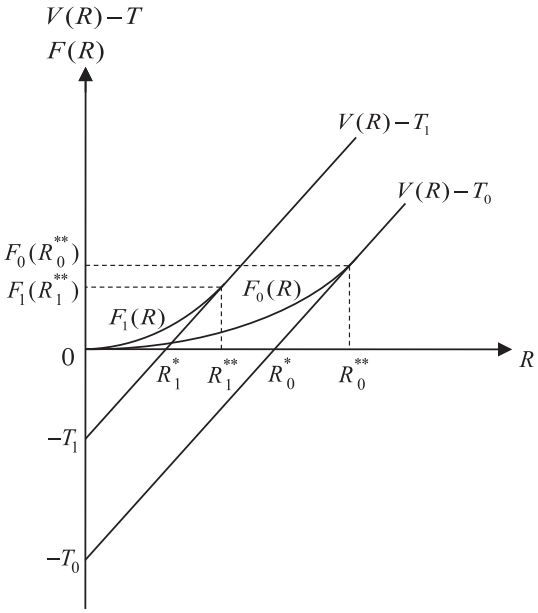

Figure 2. The effect of a decrease in transaction cost

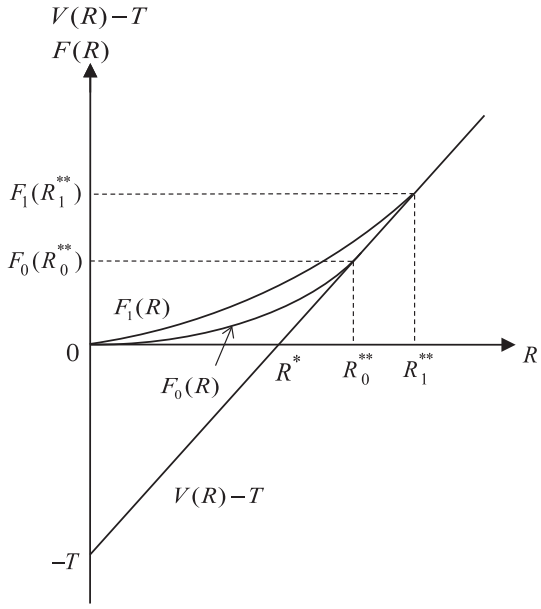

Figure 3. The effect of a growth in uncertainty

was obtained from the average of the mid-values of contract length classes weighted by the areas established as "use rights" in *Transfer and Change of Agricultural Land*.[15] The discount rate ρ, the rate of return of liquid assets as an opportunity cost of investment, was 1.0% calculated as an average of the real interest rates on time deposits in commercial banks.[16] To take into account changes in rice prices, this study estimates the option value coefficients and the transaction costs for the two periods separately. The former is the period from 1981 to 1992, in which there was an upward trend in rice prices, and the latter is the period from 1995 to 2002, which had a downward trend.[17] The number of the samples in each period is 94 and 64, respectively.

5. Estimation Results and Discussion

Table 1 shows the estimation results. The theoretical sign conditions expected in the case of a borrower's recognition of option values are all satisfied in both periods. The estimates of the transaction costs T and the option value coefficient α, representing the effect of uncertain returns on the number of farmland lease contracts, are statistically significant in both periods. The analysis provides evidence that the farmland lease market is imperfectly competitive. Since the estimates of λ are negative and insignificant, the distribution of the borrowers recognizing option values is not dominant over the distribution of the borrowers not recognizing them.[18] Each estimation result is discussed in the following subsections.[19]

1) Transaction costs T

Since a longer contract term n requires borrowers to make great effort to search for appropriate farmland, an increase in the length of a contract raises the transaction costs T. For both $V(R) = T$ and $V(R) = \alpha T$, $\partial T/\partial n > 0$ is satisfied. The transaction costs were estimated here to be 67,822 yen in the former period from 1981 to 1992 and 34,707 yen in the latter period from 1995 to 2002; representing a decrease of 51%. These are fixed costs for investments in seven-year farmland lease contracts, impossible to terminate early. As is presented in Figure 2, the reduction in the transaction costs from T_0 to T_1 implies a decrease in the option value from $F_0(R_0^{**})$ to $F_1(R_1^{**})$ and a drop in the critical value of making a contract from R_0^{**} to R_1^{**}. The above relations can be checked using equations (9) and (10). Consequently, the estimation results indicate that stable rice returns in the former period contributed to an increase in transaction costs, and the unstable rice returns in the latter period worked against the former trend. In other words, the contribution of the transaction costs to the decrease in the number of

Table 2. Profit from a farmland lease and the critical value of making a farmland lease contract (yen/10 a)

	Period from 1981 to 1992 (the former period)	Period from 1995 to 2002 (the latter period)
Critical value of making a contract considering the option value (R^{**})	21,712** (3.618)	16,355** (4.720)
Critical value of making a contract not considering the option value (R^{*})	9,981** (2.902)	5,107** (2.270)
Profit from a farmland lease (R)		
0.5–1.0 ha	−1,838	−3,416
1.0–1.5 ha	3,316	1,242
1.5–2.0 ha	8,792	4,285
2.0–3.0 ha	14,518	8,791
3.0 ha and over	21,191	12,657

Note: 1) The critical values of making a farmland lease contract considering the option value ($R^{**}=\rho\alpha T$) and the critical values not considering the option value ($R^{*}=\rho T$) were calculated from the estimated parameters.

2) For the critical values, ** indicates significant difference from zero at 1% level. Values in parenthesis are *t*-value.

3) Profit from a farmland lease R for the size class of 2.0–3.0 ha is the weighted average of profits of the size classes of 2.0–2.5 ha and 2.5–3.0 ha, and, that of the size class of 3.0 ha and over is an average of those of the size classes of 3.0–4.0 ha, 4.0–5.0 ha and 5.0 ha and over. The weight in each size class for each year in the estimation period is the number of samples in *Production Cost of Rice, Wheat and Barley*. The weights are not reported in the period from 1985 to 2002 and are therefore substituted by the values for 1984.

farmland lease contracts is greater in the former period than that in the latter period.

2) Option value coefficient α

An option value coefficient suggests the effect of uncertain returns on borrowers' behavior in the farmland lease market. The estimates of the coefficients are 2.175 in the former period, and 3.202 in the latter period. Subsequently, the option value coefficients are presented in an inverse relation to the transaction costs. As is shown in Figure 3, the critical value of making a farmland lease contract increases from R_0^{**} to R_1^{**} because of the shift of $F_0(R)$ to $F_1(R)$ caused by an increase in the option value coefficient. The option value also increases from $F_0(R_0^{**})$ to $F_1(R_1^{**})$. These relations are proved by increases in $F(R)$ and R^{**} due to the growth of $\alpha=\beta/(\beta-1)$. Accordingly, the estimation results indicate that stable rice returns in the former period contributed to a reduction in the option value coefficient, and the unstable rice returns in the latter period worked against the former trend. In other words, the contribution of uncertain returns to the decrease in the number of lease contracts is greater in the latter period than that in the former period.

3) Option value $F(R)$

The decrease in transaction costs and the increase in the option value coefficient affect $F(R)$ and R^{**} in opposite directions. As a result, the estimates of the option values are 79,715 yen in the former period and 76,430 yen in the latter period. These costs are the opportunity costs for investments in seven-year farmland lease contracts, impossible to terminate early. From the former period to the latter period, since the growth of uncertainty was offset by half the amount of the transaction cost, the option value did not decrease much.

4) Critical values R^{**} and R^{*}, and profit on farmland lease R

The possibility of making a farmland lease contract is examined by comparing the following three criteria: (1) the present profitability R of a farmland lease, (2) the critical value of making a contract with no consideration for the option value R^{*}, and (3) the critical value with consideration of the option value R^{**}. As was proved in the theoretical model, borrowers should make contracts when $R \geq R^{**}$, they

should or should not make them based on whether certain returns are acquired when $R^{**} > R \geq R^{*}$, and they should postpone them when $R^{*} > R$.

The estimates of R^{**}, R^{*} and R in each estimation period are presented in Table 2. In Table 2, in the former period, the estimates of R^{**} and R^{*} are 21,712 yen and 9,981 yen, respectively. The estimate of R by size class ranges from −1,838 to 21,191 yen. In addition, in the latter period, the estimates of R^{**} and R^{*} are 16,355 yen and 5,107 yen, respectively, and the estimate of R by size class ranges from −3,416 to 12,657 yen. Consequently, the estimates of the critical values (R^{**} and R^{*}) and the present profitability R are smaller in the latter period than those in the former period. In both periods, the relation $R^{**} > R^{*} > R$ is satisfied in the three size classes of 0.5–1.0 ha, 1.0–1.5 ha and 1.5–2.0 ha, and the relation $R^{**} > R > R^{*}$ is fulfilled in the two size classes of 2.0 ha and over. This implies that farmers in the two size classes of 2.0 ha and over make farmland lease contracts by criterion (2) and do not make lease contracts by criterion (3). By adopting the estimate of λ, the distribution of all farmers considering the option value ($p = \psi(\lambda)$) is 33.8% (setting $\lambda = -0.4188$ from Table 1) in the former period, and 38.3% (setting $\lambda = -0.2990$ from Table 1) in the latter period; otherwise, by adopting $\lambda = 0$, since the statistical significance of λ is low, the distribution is 50.0% for all farmers in both periods. In either case, more than 30% of all farmers consider the option value in both periods.

5) Disincentives for making farmland lease contracts

Summarizing the characteristics of the two estimation periods, as is well known, rice farmers enjoyed stable returns under the Food Control Law in the period from 1981 to 1992, while the unstoppable drop in rice price made returns unstable under the Law for Stabilization of Supply, Demand and Prices of Staple Food (Staple Food Act) in the period from 1995 to 2002. In the former period, the stable returns stimulated land use on both sides, e.g., borrowers' demand and lenders' reservation of the market. The transaction costs went up as the power of lenders increased due to a decrease in supply of land in the market. As a result of this, a lender's market was constructed. In the latter period, in contrast, the unstable returns prevented land use on both sides, borrowers' demand and lenders' reservation of the market. The transaction costs went down because of an increase in supply of land in the market.[20] As a result of this, a borrower's market was constructed in the latter period.

Comparing the estimation results between the former and the latter periods again, the estimates in the former period embody the characteristics of a lender's market due to the larger transaction costs and the smaller option value coefficient; on the other hand, the estimates in the latter embody the characteristics of a borrower's market caused by the smaller transaction costs and the larger option value coefficient. In short, due to the stable rice returns in the former period, an increase in demand for farmland lease was prevented by large transaction costs. In contrast, an increase in demand for farmland lease was prevented by the growth of uncertainty, resulting from a drop in profitability of rice farming in the latter period.

6) The estimation results and Kajii's hypothesis

In this section, Kajii's hypothesis is compared with the estimation results discussed above. The estimates of rice income, surplus, and *MVP* of paddy land are denoted in Table 3. Because MAFF revised the formula for calculating the depreciation of fixed assets and wage data in order to impute family labor cost in *Production Cost of Rice, Wheat and Barley* in 1991, the corresponding data in and after 1991 was modified to link to the data in and before 1990. *MVP* and surplus (A) are estimated in the dataset partially modified on the depreciation in and after 1991. Surplus (B) is calculated in the dataset partially modified on the depreciation and the family labor cost in and after 1991.[21]

In Table 3, both surpluses (A) and (B) of the size class of 3.0 ha and over exceed the rice incomes of the two size classes of less than 1.0 ha, and the surpluses of the two size classes of 2.0 ha and over exceed the rice income of the size class of less than 0.5 ha in the two periods. Consequently, Kajii's hypothesis by the average concept, which suggests that farmland mobility increases due to the relative relation between the rice income of small-size farms and the surplus of large-size farms, is satisfied in the case of relations between lenders of less than 1.0 ha and borrowers of 2.0 ha and over.

In Table 3, *MVP* exceeds both surpluses (A)

Table 3. Verification of Kajii's hypothesis (yen/10 a)

	Period from 1981 to 1992 (the former period)			
	Rice income	Surplus (A)	Surplus (B)	*MVP*
Less than 0.5 ha	45,733	−26,160	−25,877	—
0.5–1.0 ha	61,281	616	856	39,645
1.0–1.5 ha	75,865	24,774	24,978	44,799
1.5–2.0 ha	86,694	40,890	41,064	50,275
2.0–3.0 ha	95,265	53,466	53,672	56,001
3.0 ha and over	104,558	67,950	68,084	62,675
	Period from 1995 to 2002 (the latter period)			
	Rice income	Surplus (A)	Surplus (B)	*MVP*
Less than 0.5 ha	4,662	−70,986	−69,353	—
0.5–1.0 ha	25,484	−36,299	−34,966	21,663
1.0–1.5 ha	37,688	−14,263	−13,142	26,321
1.5–2.0 ha	45,065	−1,229	−229	29,365
2.0–3.0 ha	52,759	9,276	10,214	33,871
3.0 ha and over	65,602	31,884	32,612	37,736

Note: 1) Rice income and surplus are defined according to the definition in Kajii (1973). Surplus = Gross return (including byproducts) − total cost. Income from rice farming = surplus + family labor cost. Those were calculated from average data of prefectures (excluding Hokkaido and Okinawa) from "Production cost by size of paddy field rice planted area" in *Production Cost of Rice, Wheat and Barley*. The series of depreciation of fixed assets was adjusted like the data used for the estimation of variable profit function. Surplus (A) was calculated with this data, for Surplus (B), the linked data of depreciation and family labor cost calculated in the same way were used.

2) The size class of less than 0.5 ha in *Production Cost of Rice, Wheat and Barley* is divided into two classes of less than 0.3 ha and 0.3–0.5 ha until 1994. Rice income and the surplus of the size class of less than 0.5 ha in the former period are weighted averages of those two size classes. The weight is the ratio of samples in each size class for each year in the estimation period. The weights in the period from 1985 to 1992 are missing. They are substituted by the values for 1984.

3) *MVP* is the marginal value product of farmland calculated from the estimated parameters.

and (B) in all size classes excluding 3.0 ha and over in the former period. Accordingly, Kajii's hypothesis by the marginal concept, which describes whether farmland mobility increases due to the relative relation between the rice income of small-size farms and the *MVP* of large-size farms, is fulfilled more easily than the hypothesis by the average concept. Both average and marginal analyses of Kajii's hypothesis hold some validity because farmers hardly ever borrow areas next to their own; therefore, Kajii's hypothesis implies that farmland mobility should increase in the case of relations between lenders of less than 1.0 ha and borrowers of 2.0 ha and over. The above implication of Kajii's hypothesis, however, is overevaluated because it neglects the fact that 33.8 to 38.8% (setting $\lambda = -0.4188$, -0.2990, respectively), or 50% (setting $\lambda = 0$, since the statistical significance of λ is low) of all farmers actually consider the option values. The overestimated portion of farmers in the size classes of 2.0 ha and over is calculated to be 31.1 to 36.6% in the former period, and 35.4 to 39.2% in the latter period.

Summing up the theoretical and the empirical analyses presented above, previous studies assumed a perfectly competitive farmland lease market through omission of transaction costs

and uncertainty of rice returns leading to an overestimation of farmland mobility in the farmland lease contract.

6. Conclusion

The aim at the core of the Agricultural Basic Law was the improvement of the agricultural structure through the expansion of farm size. This has been one of the most important issues in agricultural policy until now because farmland mobility is not very high. Although many empirical analyses have been conducted with the aim of contributing to the improvement of the agricultural structure, farmland mobility in the lease market remains lower than predicted. This paper has argued that the assumption of a perfectly competitive market has been the cause of the failure of previous studies. In contrast to the previous studies, which assumed a perfectly competitive market, the objective of this study has been to examine farmers' behavior in the farmland lease market by using the framework of imperfect competition. This paper analyzed theoretically and empirically the effects of transaction costs and uncertain returns on rice farmers' behavior through the application of real option theory.

First, in the theoretical analysis, this paper defined three criteria for making farmland lease contracts: (1) a criterion of present profitability in a perfectly competitive market, (2) a criterion of NPV with transaction cost, and (3) a criterion taking account of transaction costs and uncertain returns. Among the three criteria, it was proved that making farmland lease contracts was easiest under criterion (1) and hardest under criterion (3). In short, the theoretical analysis showed that farmland mobility in the lease market was overevaluated in criterion (1) if the farmland lease market is imperfectly competitive.

Second, in the empirical analysis, transaction costs and the option value coefficient in criterion (3) were estimated by specifying borrowers' behavior in an imperfectly competitive market. The estimates of these parameters satisfied the theoretical sign conditions and were statistically significant; therefore, the farmland lease market was empirically proved to be imperfectly competitive. The estimates of the transaction costs, the option value coefficients, and the option values in seven-year farmland lease contracts were, respectively, 67,822 yen, 2.175, and 79,715 yen in the period from 1981 to 1992, and 34,707 yen, 3.202, and 76,430 yen in the period from 1995 to 2002. Comparing the estimates of the transaction costs and the option value coefficients between the two periods, the transaction costs were larger and the option value coefficient was smaller in the former period than those in the latter period. In other words, in the former period, which had stable rice returns under the Food Control Law, the estimate of the option value coefficient, as a measure of uncertainty, became small. The stable returns stimulated land use on both sides, e.g., borrowers' demand and lenders' reservation of the market. The transaction costs went up as the power of lenders became stronger due to a decrease in supply of land in the market. As results of this, a lender's market was constructed in the former period. On the other hand, since the unstoppable drop in rice price made rice returns unstable under the Staple Food Act, the option value coefficient became large. The unstable returns prevented land use on both sides, e.g., borrowers' demand and lenders' reservation of the market. The transaction costs went down because of an increase in supply of land in the market. As results of this, a borrower's market was constructed in the latter period. Consequently, the transaction costs in the former period and the uncertain returns in the latter period were major factors in preventing farmland lease contraction. In comparison to the above results, Kajii's hypothesis, however, overevaluated farmland mobility because it neglects the fact that from 33.8 to 38.8% (setting $\lambda = -0.4188$, -0.2990, respectively), or 50% (setting $\lambda = 0$, since the statistical significance of λ is low) of all farmers actually considered the option values. The overestimated portion of farmers in the size classes of 2.0 ha and over are from 31.1 to 36.6% in the former period, and from 35.4 to 39.2% in the latter period.

The following four points can be construed from the theoretical and the empirical analyses above[22] : (1) The farmland lease market is imperfectly competitive due to transaction costs and uncertainty of returns. (2) The previous studies assumed a perfectly competitive farmland lease market by omitting transaction costs and the uncertainty of rice returns, thus, allowing a bias in the criterion for farmland lease towards overestimation of farmland mobility. (3) Obstacles to farmland mobility include transac-

tion costs and uncertainty of returns. (4) To increase farmland mobility in the lease market, it is inadequate only to widen the productivity differential between large-size and small-size farms by structural improvement policy. The government should implement measures to reduce transaction costs and uncertainty of returns simultaneously.

1) Noringyogyo Kihon Mondai Chosakai Jimukyoku (Head Office of Investigation Committee on Fundamental Problems in Agriculture, Forestry and Fisheries) [23] argued that trying to keep the agricultural population constant by supporting agriculture without structural change seemed superficially to be humane and democratic because agricultural structural policy had to destroy the current structure and had to accelerate a polarization of farmers as a result of raising agricultural productivity. See Kusakari [17] for an outline of the agricultural policy at the core of the Agricultural Basic Law, and agricultural structural improvement.
2) By focusing on the productivity differential between size classes, Kajii's hypothesis suggests that farmland on lease contracts increase if the surplus from a large-size farm exceeds the rice income from a small-size farm. See Kajii [13]. As is commonly known, since the mid-1970s, when the government gave up on increasing farmland mobility through transfer of ownership, the main measure to expand farm size has been leasing. Kajii's hypothesis, proposed at that time, stimulated many empirical studies to prove the hypothesis.
3) See Shimamoto [25] for a detailed explanation of the historical circumstances of the policies and institutions concerning farmland mobility.
4) See Arimoto and Nakajima [1] for a review of the studies of the farmland mobility and consolidation. As Morita [22] discusses, among the previous studies, there are three definitions relating to large-size farms' capacity for paying rent in Kajii's hypothesis: (1) surplus, as in Kajii [13], Imamura [11], Hayami [9], Umemoto [32] and Hosoyama [10], (2) net return of farmland as in Inamoto [12], Miyazaki [21], Chino [3] and Tabata [28], and (3) marginal value product (*MVP*) of farmland as in the studies based on modern economics. The first two definitions are an average concept, and the last one is a marginal concept. Although the studies based on modern economics emphasize that the application of the marginal concept is appropriate from a theoretical point of view, the prediction based on the marginal concept can be overestimated due to the fact that making farmland lease contracts with a borrower's neighbors is difficult; therefore the average concept may also have some validity. Consequently, the only merit of testing Kajii's hypothesis by using the marginal concept is to evaluate family labor and owned farmland in terms of values reflecting productivity (i.e., *MVP*). However, since most of the analyses using the marginal concept redefined Kajii's hypothesis through the use of estimated parameters, a common view of how wide the differential of *MVP* of farmland between size classes has not yet been established. See Shintani [26], Kako [14], Kondo [15], and Godo [6] for analyses using the marginal concept. Note that the estimation result of Shintani [26] supports linearly homogeneous technology by using data on farms which are classed as 1.5 ha and over. Moreover, one might need to reconsider model II used in Kako [14]. While most of the studies used rice income as an indicator for small-size farms, Kako [14] and Miyazaki [21] used net return to farmland, and Godo [6] used *MVP* of farmland.
5) The methodology of testing economies of scale in rice farming is another problem derived from a poor image of the market as highlighted in Shogenji and Nakashima [27]. See also Kusakari [18].
6) According to *The Census of Agriculture* (1995) by the Ministry of Agriculture, Forestry and Fisheries (MAFF) which included a survey on the utilization of fragmented parcels of farmland, a larger farm cultivates more parcels of farmland. On average, a farmer operates eight parcels in the size class of 5.0–7.5 ha, ten parcels in the size class of 7.5–10 ha, and fourteen parcels in the size class of 10 ha and over.
7) See McDonald and Siegel [20] for the first application of real option theory and Marcus and Modest [19] for the first application of this theory in the agriculture sector. Sajiki [24], applying the theory in the dairy sector in Japan, found that investments satisfying *NPV* criterion were not made actually. Tahara [30] analyzed the impact of defective regulation on farmland conversion, and found a rise in farmland price in suburbs.
8) There are various ways in which water utilization and allocation of set-aside acreage impacts upon making farmland lease contracts. This paper has omitted their effects on farmland lease profits.
9) For simplicity, the theoretical model in Section 3 assumes that a contract term is infinite; then, in Sections 4 and 5, a real contract term is set.
10) In real option theory by Dixit and Pindyck [4], in an instance where transaction costs meet uncertainty, uncertainty of both transaction costs and returns should be taken into account. In an empirical analysis by Wossink and Gardebroek [33], incorporating uncertainty into both transaction costs and returns was not feasible because of an inconsistency between theory and practice. Hence, this paper omits uncertainty of transaction

costs.

11) The drift term corresponds to variation in expected future profits by a borrower farmer. The drift is positive when the farmer expects an increase in the future profits; otherwise the drift is negative. The Brownian motion corresponds to cyclical annual variation in profits connected to the crop year and is assumed not to be related to variations in the stock market. Farmers decide whether to make a farmland lease contract in each term. In this paper, the expected future profits are stochastic variables because profits from farmland leases follow a random walk.

12) Equation (15) was estimated by using TSP (Time Series Processor). In optimizing the objective function, a convergence criterion, the differential between previous and present values of parameters (in absolute terms), was set at 0.001 and under. Convergence was achieved after 2,096 iterations for the former period, and 3,657 iterations for the latter period. Asymptotically standard errors in Table 1 were calculated from the inverse matrix of the Hessian used in maximizing the likelihood function. Starting values for the parameters were $(\alpha,\ \lambda,\ T) = (1.5,\ 0.1,\ 68{,}000)$ for the former period, and $(\alpha,\ \lambda,\ T) = (2.0,\ 0.1,\ 35{,}000)$ for the latter period.

13) *MVP* of farmland is calculated by estimating the variable profit function,

$$\pi_R = \pi_R(p_R,\ w_C,\ w_M,\ Z_L,\ Z_A,\ t) \qquad \text{(a)}$$

where π_R, p_R, w_C, w_M, Z_L, Z_A and t are, respectively, variable profit from rice farming (i.e., rice income), rice price, intermediate input price, rental price of machinery, labor input, land input and technical indicators. To maintain the regularity conditions for estimation (i.e., monotonicity, convexity in variable input prices, concavity in fixed inputs), a prior affine transformation in Barnett [2] was applied to equation (a). See also Kusakari [16].

Following, equation (b) was obtained:

$$\pi_R^* = \pi_R^*(p_C^T,\ p_M^T,\ Z_L^T,\ Z_A^T,\ \mathrm{t}) \qquad \text{(b)}$$

where $\pi_R^* = \pi_R/p_R$, $p_i^T = p_i + \eta_i$, $p_i = w_i/p_R\ (i = C,\ M)$, and $Z_j^T = Z_j + \kappa_j\ (j = L, A)$. In addition, transformation equations are $\eta_i = \omega_i \min(p_i)$ with $|\omega_i| < 1$, and $\kappa_j = \phi_j \min(Z_j)$ with $|\phi_j| < 1$.

Specifying equation (b) in the translog form with dummy variables gives equation (c). The partial derivative of equation (c) with respect to a variable input price becomes equation (d), implying a variable profit share equation by applying Hotelling's lemma.

Hence,

$$\begin{aligned}\ln \pi_R^* &= \textstyle\sum_i \alpha_i \ln p_i^T + \sum_j \beta_j \ln Z_j^T + \beta_t t \\ &\quad + \frac{1}{2}\sum_i\sum_k \gamma_{ik} \ln p_i^T \ln p_k^T + \frac{1}{2}\sum_j\sum_l \delta_{jl} \ln Z_j^T \ln Z_l^T \\ &\quad + \sum_i\sum_l \varphi_{il} \ln p_i^T \ln Z_l^T + \sum_i \varepsilon_{it} \ln p_i^T t \qquad \text{(c)} \\ &\quad + \sum_j \mu_{jt} \ln Z_j^T t + \frac{1}{2}\beta_{tt} t^2 + \sum_s \theta_S SD_S \\ &\quad + \nu DW + \tau D91\end{aligned}$$

$$\begin{aligned}\frac{\partial \ln \pi_R^*}{\partial \ln p_i} &= \frac{\partial \ln \pi_R^*}{\partial \ln p_i^T}\,\frac{\partial \ln p_i^T}{\partial \ln p_i} - \frac{p_i^T X_i}{\pi_R^*}\,\frac{p_i}{p_i^T} \\ &= -\frac{w_i X_i}{\pi_R} \qquad \text{(d)} \\ &= \frac{p_i}{p_i^T}(\alpha_i + \textstyle\sum_k \gamma_{ik} \ln p_k + \sum_j \varphi_{ij} \ln Z_j + \varepsilon_{it} t)\end{aligned}$$

where $i = k = C,\ M,\ j = l = L,\ A$, $\gamma_{ik} = \gamma_{ki}$, and $\delta_{jl} = \delta_{lj}$. SD_S are dummy variables representing size classes (for $s = 1, \cdots, 8$, indicating, respectively, the size classes of 0.5–1.0 ha, 1.0–1.5 ha, 1.5–2.0 ha, 2.0–2.5 ha, 2.5–3.0 ha, 3.0–4.0 ha, 4.0–5.0 ha and 5.0 ha and over, 1 if in the size class, 0 if otherwise). DW is a dummy variable denoting a poor harvest year (1 if a poor harvest year, 0 if otherwise). $D91$ is a dummy variable corresponding to the revision (concerning the calculation formula for depreciation of fixed assets and wage data to impute family labor cost) of *Production Cost of Rice, Wheat and Barley* (1 if the observation was in and after 1991, 0 if otherwise).

The three estimation equations, the variable profit function (c), the variable profit share equations of current input (C) and machinery (M) in the form of equation (d) are simultaneously estimated by using the iterative estimation method of Zellner's SUR. In the estimation, the maximum log-likelihood is achieved at the transformation parameters, $\eta_C = -0.151$, $\eta_M = -0.155$, $\kappa_L = -0.073$ and $\kappa_A = -0.082$; therefore, $\omega_C = -0.18$, $\omega_M = -0.19$, $\phi_L = -0.27$ and $\phi_A = -0.27$. There is some argument as to whether the variance-covariance matrix should include transformation parameters. In this paper, because non-linear estimation, including transformation parameters as estimators, did not reach the convergence criterion, the linear SUR was carried out by a small step increment of each transformation parameter in the iteration.

The data sources are "Production cost by size class of planted area (the average of all Japan excluding Hokkaido and Okinawa)" in *Kome Oyobi Mugirui no Seisanhi* (*Production Cost of Rice, Wheat and Barley*) by MAFF, and *Nogyo Bukka Tokei* (*Statistics on Commodity Prices in Agriculture*) by MAFF. The second data source was formerly titled *Nogyo Bukka Chingin Tokei* (*Statistics of Prices and Wages in Rural Areas*) up to 1993, and then as *Noson Bukka Tokei* (*Statistics of Prices in Rural Areas*) from 1994 to 2000. The data for the eight size classes from 1970 to 2002 were pooled. Costs of current inputs ($w_C C$) consist of the expenditures on seeds and seedlings, fertilizers, agricultural chemicals, other materials, and farm buildings and structures. Costs of machinery

Appendix Table. Estimation result of variable profit function

	Transformed data		Original data	
	Estimate	*t*-value	Estimate	*t*-value
α_C	−0.3159**	(−39.157)	−0.3721**	(−39.157)
α_M	−0.6674**	(−26.616)	−0.7897**	(−26.616)
β_L	0.5944**	(4.934)	0.6409**	(4.934)
β_A	0.5194*	(2.274)	0.5657*	(2.274)
β_T	0.0195**	(4.050)	0.0195**	(4.050)
γ_{CC}	−0.3108**	(−24.071)	−0.3656**	(−21.649)
γ_{CM}	−0.1634**	(−5.439)	−0.2278**	(−5.439)
γ_{MM}	−0.9921**	(−10.835)	−1.2462**	(−10.081)
δ_{LL}	−0.8696	(−1.329)	−1.0530	(−1.385)
δ_{AL}	0.2836	(0.591)	0.3330	(0.591)
δ_{AA}	0.1026	(0.246)	0.0810	(0.161)
φ_{CL}	0.1268*	(2.310)	0.1611*	(2.310)
φ_{CA}	−0.0221	(−0.554)	−0.0284	(−0.554)
φ_{ML}	0.4642**	(2.777)	0.5922**	(2.777)
φ_{MA}	−0.0983	(−0.809)	−0.1267	(−0.809)
μ_{LT}	−0.0175	(−0.610)	−0.0188	(−0.610)
μ_{AT}	−0.0032	(−0.151)	−0.0034	(−0.151)
ε_{CT}	0.0037	(1.488)	0.0044	(1.488)
ε_{MT}	0.0106	(1.381)	0.0125	(1.381)
β_{TT}	0.0007	(0.534)	0.0007	(0.534)
θ_1	8.5265**	(15.906)	8.5265**	(15.906)
θ_2	8.6622**	(35.606)	8.6622**	(35.606)
θ_3	8.7697**	(80.550)	8.7697**	(80.550)
θ_4	8.8286**	(252.090)	8.8286**	(252.090)
θ_5	8.8737**	(410.395)	8.8737**	(410.395)
θ_6	8.9236**	(144.739)	8.9236**	(144.739)
θ_7	9.0096**	(92.170)	9.0096**	(92.170)
θ_8	9.0515**	(65.899)	9.0515**	(65.899)
τ	−0.0851**	(−5.389)	−0.0851**	(−5.389)
ν	−0.0696**	(−9.080)	−0.0696**	(−9.080)
Variable profit function Coefficient of determination: 0.989		Profit share equation of intermediate inputs Coefficient of determination: 0.699		Profit share equation of machinery Coefficient of determination: 0.730

Note: ** and * indicate significant difference from zero at 1% and 5% levels, respectively.

inputs ($w_M M$) are composed of expenditures on agricultural instruments and machinery, rentals, fees, and energy. MAFF revised the formula for calculating the depreciation of fixed assets in *Production Cost of Rice, Wheat and Barley* in 1991. To link the depreciation data, the data in and after 1991 is multiplied by the ratio between the values in 1991 calculated by new and old formulas. Current input price (w_C) and rental price of machinery (w_M) are the multilateral price indices. Labor (Z_L) is direct labor hours. Female labor hours were converted into male-equivalent labor hours by multiplying female labor hours by 0.8.

Farmland (Z_A) is the area of planted paddy field. A time trend (t) is a proxy index of technological change. A variable profit from rice farming (π_R) is the subtraction of the costs of current and machinery inputs from the gross revenue from

rice farming. The estimation result is in the Appendix Table. The conditions of monotonicity and convexity in variable input prices as well as monotonicity and concavity in fixed input quantities are all satisfied at the sample mean. By using the estimated parameters, *MVP* of farmland is calculated from equation (e).

$$\frac{\partial \pi_R}{\partial Z_A} = \frac{\pi_R}{Z_A}(\beta_A + \sum_j \delta_{jA} \ln Z_A + \sum_i \varphi_{iA} \ln p_i + \mu_{At} t) \quad \text{(e)}$$

14) The average rent of land established under "use rights" should be used in this paper. The corresponding data has been published as "Actually paid land rent by the way of making contract" in *Suiden Kosakuryo no Jittai ni Kansuru Chosa Kekka* (*The Results of the Survey of the Actual Condition of Paddy Field Rent*) by Zenkoku Nogyo Kaigisho (The National Chamber of Agriculture). However, the above data cannot actually stand time-series analysis because of changes in sample farms. Meanwhile, actual land rents in *Production Cost of Rice, Wheat and Barley* have a positive correlation with borrowers' planted area. This suggests that the land rents depend on borrowers' surplus, defined as the difference between revenue and total cost. In addition, small-class farms tend to borrow farmland at a lower rent due to personal connections. In this paper, actual land rent in *Production Cost of Rice, Wheat and Barley* is adopted after the downward bias has been removed. By using the Census data of "Cultivated land rented from others (paddy fields)" in the period from 1980 to 2005 by MAFF, annual average growth rates of cultivated land areas rented from others (paddy fields) by size class are calculated. The growth rates obtained are −18.8% for the size class of 0.5 ha and less, −2.6% for 0.5–1.0 ha, 1.4% for 1.0–1.5 ha, 6.4% for 1.5–2.0 ha, 15.7% for 2.0–3.0 ha and 49.9% for 3.0 ha and over. Hence, it appears that the most often rented land is found in the size classes of 2.0 ha and over. Land rent w is calculated as the weighted average of actual land rents (per 10 a) in the size classes of 2.0–3.0 ha and 3.0 ha and over. The weight is the ratio of samples in each size class for each year in the estimation period. The weights are not reported in the period from 1985 to 2002, and hence replaced by the values for 1984. Morita [22] has compared the three types of land rents collected in the above two data sets and in *Denbata Kakaku Oyobi Kosakuryo Shirabe* (*Survey of Farmland Price and Rent*) by Nihon Fudosan Kenkyusho (Japan Real Estate Institute).

15) The mid-value of the contract length in the "10 years and over" category is 12.5 years. The average contract length was set at 7 years since the calculated result was 7.2 years.

16) The real interest rate is the subtraction of the expected inflation rate from the interest rate on time deposits. It was assumed that the expected inflation rate in the current year matched the Consumer Price Index in the previous year. The real interest rate was set at 1.0% since the calculated real interest rate was 1.02%. The interest rate on time deposits was obtained from *Keizai Tokei Nenpo* (*Economic Statistics Annual*) by the Bank of Japan. The Consumer Price Index is the "Consumer Price Index for all items less fresh food (2005=100)" in *Shohisha Bukka Shisu* (*Consumer Price Index*) by the Ministry of Internal Affairs and Communications.

17) The amendment of the Agricultural Land Law in 1970 abolished the control of land rent, with ten years given for transition from "controlled rent" to "standard rent." The former estimation period from 1981 to 1992 was selected for two reasons: (1) the influence of this transition, and (2) the poor harvest of rice in 1993. The latter estimation period from 1995 to 2002 was selected for three reasons: (1) the enforcement of the Law for Stabilization of Supply, Demand and Prices of Staple Food in 1995, (2) the change of size classification of planted area in *Production Cost of Rice, Wheat and Barley* in 2004, and (3) a sharp rise in rice price in 2003 due to a poor harvest.

18) An estimate of λ in Table 1 needs not to be statistically significant. If it is not significantly different from zero, the distribution of all borrowers considering the option value is 50%. If $\lambda > 0$, the distribution of borrowers considering the option value is dominant over the distribution of ones not considering; otherwise, if $\lambda < 0$, the distribution of borrowers considering the option value is not dominant.

19) The estimates of the transaction costs T, the option value $F(R)$, the critical values of making farmland lease contracts R^{**} and R^{*}, and the profit from a farmland lease R are all presented in yen per 10 a.

20) Tabata [29] points out that the farmland lease market from 1990 to 1995 has strengthened the characteristics of a lender's market because of a sharp growth in the ratio of potential lenders' farmland belonging to non-farmers, old-age farmers and farmers who earned income mainly from the non-agricultural sector. A MAFF survey highlighted reasons why borrowers made lease contracts for farmland not next to their own (multiple answers were allowed). In the survey, 56% of respondents replied "because of a direct request of a lender" followed by 49% who replied "because of no lender with neighboring farmland," in *Heisei 18 Nendo Nochi no Menteki Shuseki ni kansuru Shichoson Jittai Chosa* (*the Fiscal 2006 Survey concerning Farmland Consolidation*).

21) To be able to compare the estimates of *MVP* and the estimates of either rice income or surplus

in Kajii's hypothesis in Table 3, this paper calculated these estimates as follows: First, the *MVP* was estimated by using equation (e). Second, for the estimation of rice income and surpluses (*A*) and (*B*), the data relating to the depreciation of fixed assets was modified as in the dataset for the estimation of the variable profit function. Third, for the estimation of the surplus (*B*), the data on family labor costs in and after 1991 was also adjusted because of the revision of the evaluation of the imputed wage of family labor in and after 1991.

22) The four points presented as the conclusion of the analyses of farmers' behavior in the farmland lease market in this paper are factors in the demand (for farmland lease) side. Supply-side factors, such as farmland holdings and farmland conversion could be also highlighted. See, for example, Godo [7].

References

[1] Arimoto, Y. and S. Nakajima. "Nochi no Ryudoka to Shuseki o Meguru Ronten to Tenbo (Review of Liquidization and Concentration of Farmland in Japan)," *Nogyo Keizai Kenkyu* (*Journal of Rural Economics*), Vol. 82, 2010, pp. 23–35.

[2] Barnett, W. A. "The Minflex-laurent Translog Flexible Functional Forms," *Journal of Econometrics*, Vol. 30, 1985, pp. 33–44.

[3] Chino, J. "Daikibo-Shakuchi-No no Keisei-Joken (Conditions for Forming Farmland Leasing Large-Size Paddy Farmer)," in Zenkoku Nokyo Chuokai, ed., *Suiden-Nogyo no Genjo to Yosoku* (*Present State and Prospect of Paddy Field Farming*). Tokyo: Fumin Kyokai, Part 2, Ch. 8, 1990, pp. 190–212.

[4] Dixit, A. K. and R. S. Pindyck. *Investment Under Uncertainty*, Princeton: Princeton University Press, 1994.

[5] Fujie, T. "Torihiki-Hiyo ga Nochi-Torihiki ni Oyobosu Eikyo ni Kansuru Ichikosatsu: Tansaku to Dakyo o Torikonda Nochi-Shijo Moderu no Kochiku (The Effects of Transaction Cost on Farmland Transaction: Farmland Market Model Focused on Search and Compromise)," *Nogyo Keizai Kenkyu* (*Journal of Rural Economics*), Vol. 75, No. 1, 2003, pp. 9–19.

[6] Godo, Y. "Inasaku-Keiei ni okeru Mitsumori-Rochin no Kibokan-Kakusa ga Nochi no Ryudoka ni Ataeru Eikyo (The effect of Variations in Family-Farm Laborers' Self-Estimated Wage Rates, by Farm-Size, on Land Accumulation by Large-Size Farms in the Japanese Rice Sector)," *Nogyo Keizai Kenkyu* (*Journal of Rural Economics*), Vol. 63, No. 2, 1991, pp. 110–117.

[7] Godo, Y. "Nochi-Mondai to Nihon-Nogyo (Farmland Problems and Japanese Agriculture)," in Okuno, M. and M., Honma eds., *Nogyo-Mondai no Keizai-Bunseki* (*Economic Analysis of Agricultural Problems*). Tokyo: Nihon Keizai Shimbunsha, Ch. 3, 1998, pp. 61–86.

[8] Hara, Y. *"No" o Do Toraeruka*: *Shijo-Genri-Shugi to Nogyo-Keizai-Genron* (*How Japanese Agriculture Should Be Understood: Market Fundamentalism and Principles of Agricultural Economics*). Tokyo: Shoseki Kobo Hayama, 2006.

[9] Hayami, Y. *Nogyo-Keizai-Ron* (*Agricultural Economics*). Tokyo: Iwanami Shoten, 1986.

[10] Hosoyama, T. *Nochi-Chintaishaku-Shinten no Chiiki-Sa to Daikibo-Shakuchi-Keiei no Tenkai* (*Regional Difference of the Extent of Farmland Lease and Development of Farmland Leasing Large-size Farmer*). Tokyo: Norin Tokei Kyokai, 2004.

[11] Imamura, N. "Inasaku no Kaisokan-Kakusa (Differential in Rice Farming among Size Classes)," in Nosei Chosa Iinkai ed., *Nihon no Nogyo* (*Japanese Agriculture*). Tokyo: Nosei Chosa Iinkai, 62, 1969.

[12] Inamoto, S. *Nogyo no Gijutsu-Shinpo to Kazoku-Keiei* (*Technological Progress in Agriculture and Family Farming*). Tokyo: Taimeido, 1987.

[13] Kajii, I. *Sho-Kigyo-No no Sonritsu-Joken* (*Existence Condition for Small Business Farm*). Tokyo, Tokyo Daigaku Shuppankai, 1973.

[14] Kako, T. "Inasaku no Seisan-Koritsu to Kibo no Keizaisei: Hokkaido Ishikari Chiiki no Bunseki (Efficiency and Economies of Scale in Rice Production: The Case of Ishikari Area in Hokkaido)," *Nogyo Keizai Kenkyu* (*Journal of Rural Economics*), Vol. 56, No. 3, 1984, pp. 151–162.

[15] Kondo, T. "Inasaku no Kikaika-Gijutsu to Daikibo-Shakuchi-No Seiritsu-Kanosei ni Kansuru Keiryo-Bunseki (Econometric Analysis of Mechanical Technology and the Feasibility of Leasing Large-Scale Paddy Farms)," *Nogyo Keizai Kenkyu* (*Journal of Rural Economics*), Vol. 63, No. 2, 1991, pp. 79–90.

[16] Kusakari, H. "Seisan-Yoso-Shijo to Kibo no Keizai (Input Factor Market and Scale Economies)," in Morishima, M. ed., *Nogyo-Kozo no Keiryo-Bunseki* (*Econometric Analysis of Agricultural Structure*). Tokyo: Fumin Kyokai, Part 1, Ch. 4, 1994, pp. 77–104.

[17] Kusakari, H. "Nihon no Beisaku to Kome-Seisaku no Tenkai (Rice Farming and Rice Policy in Japan)," in Okuno, M. and M., Honma eds., *Nogyo-Mondai no Keizai-Bunseki* (*Economic Analysis of Agricultural Problems*). Tokyo: Nihon Keizai Shinbunsha, Ch. 5, 1998, pp. 115–141.

[18] Kusakari, H. "Shinshukuteki-Shuho to Shinshukuteki-Shiko: Seisan-Kansu-Bunseki no Hokosei ni Kansuru Komento (Flexible Method and Flexible Thought)," in Izumida, Y. ed., *Kindai-Keizaigakuteki Nogyo/Noson no 50 Nen* (*Theoretical Economics and Agriculture: Fifty Years of Analy-*

sis). Tokyo: Norin Tokei Kyokai, 2005, pp. 159–169.

[19] Marcus, A. J. and D. M. Modest. "Futures Markets and Production Decisions," *The Journal of Political Economy*, Vol. 92, 1984, pp. 409–426.

[20] McDonald, R. and D. Siegel. "The Value of Waiting to Invest," *The Quarterly Journal of Economics*, Vol. 101, 1986, pp. 707–728.

[21] Miyazaki, T. "Suiden-Nogyo no Tenkai to Chidai/Chika-Mondai (Issues on Rent and Value of Paddy Field at the Present Stage)," *Noringyo Mondai Kenkyu* (*Journal of Rural Problem*), No. 89, 1987, pp. 177–185.

[22] Morita, K. "Kinnen no Suiden-Shakuchiryo-Suijun to Inasaku-Seisanryoku no Kaisokan-Kakusa: Kakusa no Jittaika no Tokeiteki-Kakunin (Trend of Paddy Field Rent and Differentials of Productivity among the Big- and the Small-Sized Farms: Statistical Observations of Materialization of Scale Economy)," *Nogyo Keizai Kenkyu* (*Journal of Rural Economics*), Vol. 59, No. 4, 1988, pp. 208–218.

[23] Noringyogyo Kihon Mondai Chosakai Jimukyoku, *Nogyo no Kihon Mondai to Kihon Taisaku "Kaisetsuban"* (*Fundamental Problems of Japanese Agriculture and Basic Measures* (*Commentaries*)). Tokyo: Norin Tokei Kyokai, 1960.

[24] Sajiki, T. "Riaru/Opushon-Bunseki ni yoru Rakuno-Shingijutsu-Donyu no Saiteki-Toshi Taimingu (Real Options Analysis for Optimal Timing of Dairy Technology Adoption Decisions)," *2005 Nendo Nihon Nogyo Keizai Gakkai Ronbunshu* (*Journal of Rural Economics Special Issue 2005*). Tokyo: Nosangyoson Bunka Kyokai, 2006, pp. 73–80.

[25] Shimamoto, T. *Gendai Nochi Chintaishaku Ron* (*Study on Modern Farmland Lease*). Tokyo Norin Tokei Kyokai, 2001.

[26] Shintani, M. "Suitosaku Kikaika no Keizaiteki-Hyoka (Economic Evaluation of Mechanization in Paddy Field-Rice Farming)," *Nihon-Nogyo no Seisan-Kansu-Bunseki* (Production Function Analysis of Japanese Agriculture). Tokyo: Taimeido, 1983, pp. 163–181.

[27] Shogenji, S. and Y. Nakashima. "Nogyo-Kozo-Mondai to Yoso-Shijo (Agricultural Structure Problems and Factors Market)," in Nakayasu, S. and F. Egaitsu, eds., *Nogyo-Keizai-Kenkyu no Doko to Tenbo* (*Trends and Prospects in Agricultural Economic Studies*). Tokyo: Fumin Kyokai, 1996, pp. 106–118.

[28] Tabata, T. "Nochi-Ryudoka to Chika/Chidai/Rochin (Farmland Mobility and Land Price, Rent and Wage)," in Ishiguro, S. and A. Kawaguchi, eds., *Nihon-Nogyo no Kozo to Tenkai-Hoko* (*The Structure and Development of Japanese Agriculture*). Tokyo: Norin Tokei Kyokai, 1984, pp. 233–280.

[29] Tabata, T. "Shin-Shokuryohoka ni okeru Nogyo-Kozo no Doko to Tenbo (Trends and Prospects for the Structural Changes in Japanese Agriculture under the Staple Food Law)," *Nogyo Keizai Kenkyu* (*Journal of Rural Economics*), Vol. 69, No. 2, 1997, pp. 90–102.

[30] Tahara, K. "Nihon ni Okeru Tenyo-Kisei to Nochi-Kakaku: Tenyo-Kisei no Jikkosei ni Kansuru Keiryo-Bunseki (An Econometric Analysis of Efficacy of Regulation on Farmland Conversion by Means of Farmland Price Data in Japan," *2005 Nendo Nihon Nogyo Keizai Gakkai Ronbunshu* (*Journal of Rural Economics Special Issue 2005*). Tokyo: Nosangyoson Bunka Kyokai, 2006, pp. 89–96.

[31] Takahashi, D. "Farmland Liquidization and Transaction Costs," *The Japanese Journal of Rural Economics*, Vol. 14, 2012, pp. 1–19.

[32] Umemoto, M. *Suidensaku-Keiei no Kozo to Kanri* (*Structure and Management of Paddy Field-Rice Farm*). Tokyo: Nihon Keizai Hyoronsha, 1997.

[33] Wossink, A. and C. Gardebroek. "Environmental Policy Uncertainty and Marketable Permit Systems: The Dutch Phosphate Quota Program," *American Journal of Agricultural Economics*, Vol. 88, 2006, pp. 16–27.

(Received September 21, 2012; accepted January 25, 2013)