A Microeconomic Analysis of Production Behavior of the Farm Household in Japan*

—— A Profit Function Approach ——

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1. Introduction

The purpose of this study is to gain a better understanding of the farm household behavior in production under the rapidly changing economic conditions during the postwar period, especially during the mid–1960's. We shed special light on farmers' responsiveness to prices in the supply of farm products and the demand for variable inputs such as labor, fertilizer, feed, and agri–chemicals. For this purpose, we employ the profit function approach and we estimate the relevant factor demand and output supply functions.

Shephard [1953] and Uzawa [1964] were among the first to focus on the profit function as an operational tool based on the dual of the production function. Since McFadden [1966] suggested a method for its derivation, the theory of the profit function and its empirical implementaion have been developed by Lau, Yotopoulos, and others[1]. Moreover, an approach through the theory of the profit function has unique advantages for constructing a model to explain the farm household behavior within the "subjective equilibrium" framework. Torii [1969] summarizes the theoretical significance as follows[2]:

> In traditional models of subjective equilibrium of the farm household, the theoretical features of the farm household as a producing unit have been ignored. The marginal productivity conditions, which guarantee the maximization of the income–leisure preference function, do not always satisfy the equilibrium conditions for profit maximization on the production side of the farm household. In other words, this implies that the model of endogenous determination of the individual output supply and factor demand is not included in the system.

Our model of the profit function and the factor demand and output supply functions associated with it offer a solution to this problem. Indeed, our analysis of the production side of the household behavior is a part of our comprehensive model for explaining the behavior of the farm household as a "firm–household complex" through the theory of subjective equilibrium[3].

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1) For the theoretical development, refer to Lau [1969a, 1969b] and as empirical applications of the theory of the profit and factor demand functions see Lau and Yotopoulos [1971, 1972, 1973], Yotopoulos, Lau and Lin [1975], Yotopoulos and Nugent [1976], and Adulavidhaya, Kuroda, Lau and Yotopoulos [1975].

2) The paper is written in Japanese. The English translation is by the authors.

3) A complete model of subjective equilibrium is given in Kuroda [1975]. The possibility of an independent analysis of the production behavior of the farm household was suggested by Jorgenson and Lau

2. Conceptual and Theoretical Framework

2. 1 The Cobb–Douglas Profit Function[4)]

We assume the following production function for the farm–firm[5)].

$$Y=F(X_1, X_2, X_3, X_4\,;\; K_1, K_2, K_3, K_4) \qquad (2\text{–}1)$$

where Y is the quantity of output, X_1, X_2, X_3, and X_4 are the quantities of labor, fertilizer, feed, and agri–chemicals in order, and K_1, K_2, K_3, K_4 are the amounts of machinery capital, plant capital, animal capital, and farm land in order.

The variables X_1, X_2, X_3, and X_4 are considered to be variable factors of production, while K_1, K_2, K_3, and K_4 are assumed to be fixed factors of production. The detailed definitions of these variables will be given in Appendix A. Two points deserve further notice. The explicit introduction of the four variable factors, labor, fertilizer, feed, and agri–chemicals, will lead us to estimating the farm–firm's demand for such important factors of production during the postwar period. Second, the fixed factors are extremely important for investigating the effects of farm mechanization, investments in plant and animal capital, and of land holding system on agricultural production and hence on the output supply and on the input demand for the variable factors of production.

We specify the production function given in (2–1) as a Cobb–Douglas type,

$$Y=A\left[\prod_{i}^{4} X_i^{\alpha_i}\right]\left[\prod_{j}^{4} K_j^{\beta_j}\right], \quad i=1, 2, 3, 4, \quad j=1, 2, 3, 4, \qquad (2\text{–}2)$$

where A is a technical efficiency parameter, and α_i's and β_j's are the output elasticities with respect to the variable inputs and the fixed inputs, respectively. We assume the sum of α_i's to be less than unity, indicating decreasing returns to scale in the variable factors of production, i. e.,

$$\mu\equiv\sum_{i=1}^{4} \alpha_i<1, \quad i=1, 2, 3, 4. \qquad (2\text{–}3)$$

If we assume that the farm–firm maximizes its profit, a profit function corresponds as a dual to the production function given in (2–2)[6)]. However, the farm–firm may not *perfectly* maximize its profit within a given period of time, say one year. For such a firm, the marginal conditions may be written as,

$$\frac{\partial Y}{\partial X_i}=k_i q_i, \quad i=1, 2, 3, 4, \qquad (2\text{–}4)$$

where q_i's are the prices of the variable inputs deflated by the output price, P_A and k_i's are constants and considered as behavior parameters which indicate the decision rule that describes the farm–firm's profit–maximizing behavior with respect to the variable factors of production. A special case where $k_i=1$ for all i implies that the marginal product of each variable factor of production is equal to the normalized price of that factor, i. e., perfect profit maximization. This modification through the introduction of the farm–firm specific

[1969] on the assumption that there exist markets for variable factors of production.

4) This draws heavily on Lau and Yotopoulos [1971], and Yotopoulos and Nugent [1976] for the purpose of constructing a model suitable for our specific analysis.

5) We use the word "farm–firm" when we treat the farm household as a producer of agricultural commodities.

6) For details on the theory of duality, refer to Shephard [1953], Uzawa [1964], McFadden [1970], and Lau [1969].

k_i's may be rationalized in terms of at least two reasons. First, there may exist a consistent over– or under– evaluation of prices of the variable inputs by the farm–firm. Second, there may exist a divergence between the expected and the actual normalized prices of variable inputs. We may interpret the k_iq_i's as the normalized "effective" prices specific to the farm–firm. The farm–firm can then be viewed as a profit maximizer subject to the "effective" prices of the variable factors of production.

With the introduction of the normalized effective prices, the normalized profit function can be given by,

$$\text{(2–5)} \qquad \Pi_a = A^*\left[\prod_i^4 (q_i)^{\alpha_i^*}\right]\left[\prod_j^4 (K_j)^{\beta_j^*}\right], \quad i=1, 2, 3, 4, \quad j=1, 2, 3, 4,$$

where we define

$$\text{(2–6)} \qquad A^* \equiv \left[A^{(1-\mu)^{-1}}\left(1-\sum_{i=1}^4 \frac{\alpha_i}{k_i}\right)\right]\left[\prod_i^4 (k_i)^{-\alpha_i(1-\mu)^{-1}}\right]\left[\prod_i^4 (\alpha_i)^{\alpha_i(1-\mu)^{-1}}\right], i=1, 2, 3, 4,$$

$$\text{(2–7)} \qquad \alpha_i^* \equiv -\alpha_i (1-\mu)^{-1} < 0, \quad i=1, 2, 3, 4,$$

$$\text{(2–8)} \qquad \beta_j^* \equiv \beta_j (1-\mu)^{-1} > 0, \quad j=1, 2, 3, 4.$$

Furthermore, to simplify notations later on, let us define a component of A^* in (2–6) as

$$\text{(2–9)} \qquad k^* \equiv \left(1-\sum_{i=1}^4 \frac{\alpha_i}{k_i}\right)(1-\mu)^{-1}, i=1, 2, 3, 4.$$

The factor demand functions can be given by,

$$\text{(2–10)} \qquad X_i = -A^*\alpha_i^* (k_i)^{-1} (q_i)^{-1} (k^*)^{-1}\left[\prod_i^4 (q_i)^{\alpha_i^*}\right]\left[\prod_j^4 (K_j)^{\beta_j^*}\right],$$
$$i=1, 2, 3, 4, \quad j=1, 2, 3, 4,$$

or, by multiplying both sides of (2–10) by $-\dfrac{q_i}{\Pi_a}$, we have

$$\text{(2–11)} \qquad -\frac{q_iX_i}{\Pi_a} = (k_i)^{-1} (k^*)^{-1} \alpha_i^* = \alpha_i^{*\prime}, \quad i=1, 2, 3, 4.$$

In other words, in (2–11) we allow for the elasticities of input demand estimated from the factor demand functions, $\alpha_i^{*\prime}$, to be different from the respective elasticities estimated from the profit function, α_i^*, as long as $(k_i)^{-1}(k^*)^{-1} \neq 1$[7].

The output supply function can be given by,

$$\text{(2–12)} \qquad Y = A^*\left(1-\sum_{i=1}^4 \frac{\alpha_i}{k_i}\right)^{-1}\left[\prod_i^4 (q_i)^{\alpha_i^*}\right]\left[\prod_j^4 (K_j)^{\beta_j^*}\right],$$
$$i=1, 2, 3, 4, \quad j=1, 2, 3, 4.$$

It should be emphasized at this point that X_i's, Y, and Π_a are all the *actual* quantities of the variable inputs, output, and normalized profit (i. e., current revenues less current total variable costs divided by the output price). We thus call the functions given in (2–5), (2–11), and (2–12) the *actual* profit, factor demand, and output supply functions.

There are a number of advantages in working with the profit function. Besides those noted in section 1, we add here two other important advantages. First, the profit function, the supply function, and the derived demand functions for the variable factors of production

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7) There are possibilities for $(k_i)^{-1}(k^*)^{-1}=1$, i. e., $k_i\left(1-\sum \frac{\alpha_i}{k_i}\right) = (1-\sum \alpha_i)$, which does not necessarily imply $k_i=1$ for $i=1, 2, 3, 4$. We consider those possibilities as special cases where the farm–firm perfectly maximizes its profit.

are functions only of the normalized prices of the variable inputs and of the quantities of the fixed inputs. These variables are normally considered to be determined independently of farm–firm's behavior. Econometrically, this implies that they are exogenous variables, and by estimating these functions simultaneously we avoid the problem of simulteneous equations bias to the extent that it is commonly present in production analysis. Second, as mentioned already in section 1, our interest is directed to an empirical analysis of how the farm–firm changes the supply of output and the demand for variable inputs in response to changes in the respective prices. For this purpose, studies using production function will not suffice, since they do not tell us the farm–firm's responsiveness to prices. An introduction of the profit and factor demand functions, however, can meet this objective.

2. 2 Tests of Hypotheses

2. 2. 1 Profit Maximization

The assumption of profit maximization is a maintained hypothesis in our model which is statistically testable. We shall test the null hypothesis of (*perfect*) profit maximization, i. e., $H_0 : \alpha_i^* = \alpha_i^{*\prime}$ for $i=1, 2, 3, 4$, as it applies to the farm–firm. The rejection of this hypothesis implies that the farm–firm does not perfectly maximize its profit with respect to the levels of the utilization of the variable inputs, in our case farm labor, fertilizer, feed, and agri-chemicals. As an alternative, it may be following a maximization rule that equates the marginal value products of the variable inputs to their "effective" prices specific to the farm–firm. On the other hand, if we cannot reject the hypothesis, it then implies that the farm–firm is a perfect profit maximizer, equating the marginal value products of the variable inputs to their market prices which are specific to the farm–firm. In this case, we will obtain $k_i=1$ for $i=1, 2, 3, 4$, in equation (2–11).

2. 2. 2 Returns to Scale

A casual examination of evidence shows that, during the postwar years, the number of farm households that cultivate less than one hectare has been decreasing while the number of farm households with larger farm operations has been increasing. This is *prima facie* evidence for the existence of economies of scale in agricultural production during the postwar years. A statistical test of the null hypothesis of constant returns to scale in our study will provide a definite answer to this question, which is of critical importance in the light of a contemporary agricultural problem of how to increase the supply of food commodities.

In our framework, a test of the null hypothesis of constant returns to scale in all inputs in the case of Cobb–Douglas production function amounts to testing the null hypothesis, $H_0 : \sum_{j=1}^{4} \beta_j^* = 1$, where β_j^*'s are the elasticities of the profit function with respect to the fixed inputs. If $\sum_{j=1}^{4} \beta_j^* > 1$, then there exist increasing returns to scale, and if $\sum_{j=1}^{4} \beta_j^* < 1$, then there exist decreasing returns to scale[8].

2. 3 Procedure for Empirical Estimation

The profit function in (2–5), the four factor demand functions in (2–11), and the output supply function in (2–12) form a system of six equations which can be estimated simultaneously. However, because of the duality between the profit function and the output supply function, one equation is redundant in the system. Either the profit or the supply function

8) For the detailed derivation of the procedure of testing the hypothesis of returns to scale from a Cobb–Douglas profit function, refer to Lau and Yotopoulos [1972].

must be dropped from the simultaneous equations system in the empirical estimation in order to obtain a non-singular matrix. We will then estimate the profit and the four factor demand functions simultaneously. Given the estimates of these five functions, the output supply function can immediately be obtained through equation (2-12).

In order to capture differences in technical efficiencies and differences in climatic effects on profit-maximizing farm-firms among regions, we introduce eleven regional dummy variables $D_l\,(l=1, \cdots, 11)$ in the profit function. Thus, the estimating equations are[9]:

$$\ln \Pi_a = \ln A^* + \sum_{i=1}^{4} \alpha_i^* \ln X_i + \sum_{j=1}^{4} \beta_j^* \ln K_j + \sum_{l=1}^{11} d_l D_l \tag{2-13}$$

$$-\frac{q_i X_i}{\Pi_a} = \alpha_i^{*\prime} \tag{2-14}$$

where $i=1, 2, 3, 4, j=1, 2, 3, 4, l=1, 2, \cdots, 11$.

At this point, it is relevant to say a word about the stochastic specification of the model. Given the assumptions that the farm-firm is profit-maximizing and price-taking, the production function is concave in the variable inputs, and the quantities of the fixed inputs are constant in the short run, the farm-firm's decision variables are the quantity of output and the variable inputs. The price of output and the prices of the variable inputs as well as the quantities of the fixed inputs are predetermined and not subject to changes by the action of any one firm in the short run. On the other hand, output and labor, fertilizer, feed, and agri-chemicals are jointly dependent variables.

Because of the profit identity, i. e., profit is equal to current revenue less current variable costs, an alternative set of five jointly dependent variables consists of profit and expenditures on each of the four variable inputs. Given the predetermined variables, there is a one-to-one correspondence between profit and expenditures on each variable input and the quantities of output and of each variable input. Thus, in the equations in (2-13) and (2-15), the variables on the left hand side are the jointly dependent variables and those on the right hand side include only the predetermined variables.

For the stochastic specification of the model in the statistical estimation, we will follow the usual assumption of an additive error with zero expectation and non-zero finite variance for each of the five equations given in (2-13) through (2-14). The additive error in the four factor share equations given in (2-14) may arise from differential abilities to maximize profit or divergence between expected and realized prices. However, non-zero covariances of the five equations are assumed for the same farm-firm. In other words, the dependent variables of the five equations can be mutually interdependent. The covariances of the errors of each equation corresponding to different farm-firms are assumed to be zero. With this specification of errors, Zellner's [1962] method of asymptotically efficient estimation is used. According to this method, the efficiency of estimation can be increased through the imposition of restrictions on the coefficient, if this is required[10].

9) Eleven regions are introduced as dummy variables. They are Tōhoku, Hokuriku, Kita-Kantō, Minami-Kantō, Tōzan, Tōkai, Kinki, San-in, San-yō, Shikoku, and Kita-Kyūshū. Note that these dummy variables do not enter the factor demand functions since they are offset in the process of the derivation of the factor demand functions.

10) Not much is known about how stochastic disturbance terms should be introduced into economic relationships. Hoch [1958], Mundlak and Hoch [1965], and Zellner, Kmenta, and Drèze [1966] have

Table 4-1 Cobb -Douglas Profit and Factor Demand Functions 1965

Variable	Parameter	Zellner's Efficient Estimation: No Rest.	Zellner's Efficient Estimation: 4 Rest. $\alpha_i^*=\alpha_i^{*\prime}(i=1,\cdots,4)$
Π fn			
const.	$\ln A^*$	1.145* (2.477)	1.435* (6.986)
$\ln q_1$	α_1^*	−0.1366 (−0.6912)	−0.5493* (−22.30)
$\ln q_2$	α_2^*	−0.0864 (−1.166)	−0.1251* (−29.80)
$\ln q_3$	α_3^*	−0.0998 (−0.4482)	−0.2661* (−11.11)
$\ln q_4$	α_4^*	−0.0028 (−0.0358)	−0.0420* (−20.93)
$\ln K_1$	β_1^*	0.0915 (1.031)	0.2806* (7.013)
$\ln K_2$	β_2^*	0.0739* (2.574)	0.1038* (3.092)
$\ln K_3$	β_3^*	0.0487 (1.666)	0.0280 (0.8123)
$\ln K_4$	β_4^*	0.8963* (7.413)	0.7319* (26.22)
D_1	d_1	0.5560* (4.813)	0.5906* (5.577)
D_2	d_2	0.5549* (3.456)	0.5400* (4.705)
D_3	d_3	0.7322* (3.903)	0.5606* (5.461)
D_4	d_4	0.7701* (3.611)	0.6641* (6.304)
D_5	d_5	0.5716* (3.464)	0.3745* (3.273)
D_6	d_6	0.6499* (3.110)	0.4375* (4.115)
D_7	d_7	0.3426 (1.635)	0.2768* (2.362)
D_8	d_8	0.2446* (1.944)	0.1431 (1.370)
D_9	d_9	0.3168* (2.020)	0.2772* (2.570)
D_{10}	d_{10}	−0.0984 (−0.7392)	−0.2375* (−1.975)
D_{11}	d_{11}	0.2475* (1.971)	0.2049* (1.936)
$\sum_{j=1}^{4}\beta_j^*$		1.1104	1.1443
Labor Demand fn	$\alpha_1^{*\prime}$	−0.5787* (−22.75)	−0.5493* (−22.30)
Fert. Demand fn	$\alpha_2^{*\prime}$	−0.1280* (−32.14)	−0.1251* (−29.80)
Feed Demand fn	$\alpha_3^{*\prime}$	−0.2917* (−11.87)	−0.2661* (−11.11)
Ag. Ch. Demand fn	$\alpha_4^{*\prime}$	−0.0427* (−28.16)	−0.0420* (−20.93)

Notes: 1) Figures in parentheses are computed t-ratios.
2) Coefficients with * indicate the statistical significance at the 5 percent level.

3. Data

The main source of data used in our study is *Nōka Keizai Chōsa Hōkoku* (Report on the Economic Survey of Farm Households) published annually by the Japanese Ministry of Agriculture and Forestry (hereafter NKCH). Our estimates are based on the 1965 data.

The computation of prices of output and of the variable inputs specific to farm-firms is of critical importance for our model. We used data from 1965 *Nōka Butsuzai Tōkei* (Statistical Survey on Commodities of Farm Households) (NBT hereafter) in order to compute the farm-specific variable input prices. For the farm-firm specific output price we relied on the estimates by Torii [1971].

Our sample consists of the "average farms" in each of the six size classes for the twelve regions of the country (exclusing Hokkaidō)[11]. The details of definitions of the variables in our model are given in Appendix A.

proposed one possible assumption workable in the case of Cobb-Douglas production functions. Nerlove [1960] derives an additive error to the natural logarithm of the cost function. We followed his procedure assuming that farm-firms maximize profit subject to unknown exogenous disturbances.

11) The six size classes are 0.1∼0.3 ha, 0.3∼0.5 ha, 0.5∼1.0 ha, 1.0∼1.5 ha, 1.5∼2.0 ha, and 2.0 ha and over. The twelve regions are the eleven regions given in note 9 plus Minami-Kyūshū.

4. Empirical Results

In our model, the estimation of the profit and factor demand functions precedes an estimation of the output supply function. The estimated results of the profit and factor demand functions for 1965 are presented in Table 4–1.

4.1 Tests of Hypotheses

First, we tested the null hypothesis of (perfect) profit maximization, i. e., $H_0: \alpha_i^* = \alpha_i^{*\prime}$ for all $i(=1, 2, 3, 4)$ jointly. A F–test was used for this purpose. The computed F (4,336) is 2.68. Since the critical value of F (4,336) is 3.32 at the one percent level of statistical sighificance, we could not reject the null hypothesis. This implies that the farm–firm (perfectly) maximizes its profit with respect to the levels of utilization of the variable inputs and that the constants k_i's in (2–4) are unity for all $i(=1, 2, 3, 4)$.

Next, we tested the null hypothesis of constant returns to scale in agricultural production of farm–firms based on the validity of (perfect) profit maximization. The computed F (1,340) is 59.1 but the critical F (1,340) is equal to 6.63. Thus, we rejected the null hypothesis of constant returns to scale. $\sum_{j=1}^{4} \beta_j^*$ given in the third column of Table 4–1, 1.1104, together with the result of the hypothesis testing, indicates existence of increasing returns to scale. We then computed the confidence interval of the estimated $\sum_{j=1}^{4} \beta_j^*$ with the probability 0.95. The computed confidence interval is given as $1.1079 < \sum_{j=1}^{4} \beta_j^* < 1.1129$. This interval obviously exists at a region larger than one. We may therefore conclude that increasing returns to scale exist in agricultural production. This finding will give an empirical answer to an intuitive question of existence of increasing returns to scale in agricultural production after 1960 or at least during the mid–1960's which is based on a statistical observation of an increase in the number of larger scale farms at the expense of smaller scale farms.

Based on the results of tests we re–estimated the profit and factor demand functions with only equality restrictions, i. e., $\alpha_i^* = \alpha_i^{*\prime}$, $i=1, 2, 3, 4$. The estimates are presented in the last column of Table 4–1. As seen clearly, the statistical significance of the estimated coefficients has been drastically increased. This is the final specification of the profit and factor demand functions in our study and is used for further analysis.

4.2 The Output Supply and Factor Demand Behavior of the Farm–Firm

Since $k_i=1$ for all $i(=1, 2, 3, 4)$, the estimating equation of the output supply of the farm–firm is given from (2–12) as,

$$(4-1)\quad \ln Y = -\ln\left(1-\sum_{i=1}^{4}\alpha_i^*\right) + \ln A^* + \alpha_1^*\ln q_1' + \alpha_2^*\ln q_2' + \alpha_3^*\ln q_3' + \alpha_4^*\ln q_4' - \left(\sum_{i=1}^{4}\right)\alpha_i^*\ln p_A + \beta_1^*\ln K_1 + \beta_2^*\ln K_2 + \beta_3^*\ln K_3 + \beta_4^*\ln K_4 + \sum_{i=1}^{11} d_i D_i.$$

Next, we assume the disturbance terms of the four factor share equations in (2–14) to be zeros. Then, taking the natural logarithms of both sides of the equations in (2–14) and substituting the profit function given in (2–13), we can obtain the four factor demand functions for labor, fertilizer, feed, and agri-chemicals. As an example, only labor demand equation is shown here.

$$(4-2)\quad \ln X_1 = \ln(-\alpha_1^*) + \ln A^* + (\alpha_1^*-1)\ln q_1' + \alpha_2^*\ln q_2' + \alpha_3^*\ln q_3' + \alpha_4^*\ln q_4' + \left(1-\sum_{i=1}^{4}\alpha_i^*\right)\ln p_A + \beta_1^*\ln K_1 + \beta_2^*\ln K_2 + \beta_3^*\ln K_3 + \beta_4^*\ln K_4 + \sum_{i=1}^{11} d_i D_i.$$

Note here that we introduced the relationship $q_i = q_i'/p_A$ for $i=1, 2, 3, 4$. The estimated elasticities of the output supply and factor demand with respect to the exogenous variables are given in Table 4–2. These estimates are based on the coefficients given in the last column in Table 4–1.

Table 4–2 Computed Elasticities of Output Supply and Factor Demand, 1965

Endogenous Var. / Exogenous Var.	Output Supply ($\ln Y$)	Labor Demand ($\ln X_1$)	Fertilizer Demand ($\ln X_2$)	Feed Demand ($\ln X_3$)	Agri. Chem. Demand ($\ln X_4$)
$\ln q_1'$	−0.5493	−1.5493	−0.5493	−0.5493	−0.5493
$\ln q_2'$	−0.1251	−0.1251	−1.1251	−0.1251	−0.1251
$\ln q_3'$	−0.2661	−0.2661	−0.2661	−1.2661	−0.2661
$\ln q_4'$	−0.0420	−0.0420	−0.0420	−0.0420	−1.0420
$\ln p_A$	0.9825	1.9825	1.9825	1.9825	1.9825
$\ln K_1$	0.2806	0.2806	0.2806	0.2806	0.2806
$\ln K_2$	0.1038	0.1038	0.1038	0.1038	0.1038
$\ln K_3$	0.0280	0.0280	0.0280	0.0280	0.0280
$\ln K_4$	0.7319	0.7319	0.7319	0.7319	0.7319

Notes: 1) Elasticities were computed using the estimates reported in the last column in Table 4-1.
2) For the procedure of the estimation of elasticities, see text.

4. 2. 1 The Supply of Output

The estimated elasticities of output supply of the farm–firm are presented in the first column of Table 4–2. As we expected *a priori* from the theory of the profit and factor demand functions, the supply elasticities with respect to the input prices are negative, while those with respect to the output price and the fixed variables are positive. In general, our results show the farm–firm's responsiveness of the supply of output to changes in prices. They also indicate the importance of increase in farm land for an increased supply of farm products. Furthermore, a 10 percent increase in the price of farm labor, i. e., farm wage rate, will decrease the output supply of the farm–firm by 5 percent, indicating that the rapid increase in farm wage rates during the 1960's had a relatively serious negative effect on the supply of output by the farm–firm.

Above all, our most interesting elasticity is the own price elasticity. In our results it is around unity, which indicates that the farm–firm behaved rather elastically during the

Table 4–3 Estimates of Output Supply Elasticities by Other Researchers, Japan

Researcher	Products	Estimated Period	Elasticity	
			Short Run	Long Run
Tsuchiya, K.[1]	Wheat	1901–1960	0.190	1.497
	Barley	1901–1960	0.175	1.049
Le Than Nghiep[2]	Rice	1955–1969	0.61	2.52
Yuize, Y.[3]	Aggregated products	1952–1962	0.420	0.552
Akino, M.[4]	Aggregated products	Postwar years	0.149	0.413

Sources: 1) Tsuchiya, K. [1962], chapter 7, "Mugi-ka ni taisuru Nōmin no Chōkiteki Hannō (Farmers' Long-Term Response to Prices of Wheat and Barley)," pp. 182—214.
2) Le Than Nghiep [1973].
3) Yuize, Y. [1965].
4) Akino, M. [1971].

mid–1960's with respect to changes in the output price.

Let us here compare our estimates with other researchers' estimates of output supply elasticities. Studies in this area are very few in Japan. More specifically, we know of no study of the output supply at the micro level for Japan. In Table 4–3 we report the estimates of other researchers at aggregated levels. The elasticities of wheat and barley by Tsuchiya [1962] and the elasticity of rice by Le Than Nghiep [1973] give the acreage responsiveness to changes in output price of aggregated products. Yuize [1965] estimates the elasticities of aggregated products with respect to the output price. All the above researchers employed the Nerlove's [1958] method for the short run and long run estimation. Akino [1971] introduced a new method to estimate the output supply elasticity with respect to own price developed by Cowling, Metcalf and Rayner [1970]. That is, he estimated the output supply elasticity by the demand and supply elasticities of factors of production.

Although these estimates, which are at the macro level, may not be directly comparable to our results, they are still suggestive in the analysis. Two points are clear from these estimates. First, farm–firms respond positively to changes in the price of output in their output supply and relatively more elastically in the long term. Second, the elasticities of individual commodities are larger than the elasticity of the aggregated commodities. This tendency may be caused by offsetting substitutions of one product for another in the agricultural production by farm–firms. Our estimate of almost unitary own–price elasticity of the output supply at the farm–firm level is comparable to those obtained by Yuize and Akino from macro–data, of 0.552 and 0.413, respectively. Based on our estimate of the own price elasticity of the output supply by the farm–firm together with the other researchers' estimates, we may conclude that farm–firms respond positively and rather elastically to changes in the output price in the supply of farm products. We do not observe any "rigidity of farm output supply" either at the micro level or at the macro level.

4. 2. 2 The Demand for Variable Factors of Production

The elasticities of demand for labor, fertilizer, feed, and agri–chemicals are presented, respectively, in columns 2, 3, 4, and 5 in Table 4–2. Again, as in the case of the output supply, we expected *a priori* from the theory of the profit and factor demand functions the negative responsiveness of the demand for the variable factors of production with respect to the input prices and the positive responsiveness with respect to the output price and the quantities of the fixed inputs.

First, the elasticities of the demand for the variable inputs with respect to their own prices are all greater than one. This indicates that the farm–firm responds elastically to changes in the input prices in the demand for the variable inputs, in our case labor, fertilizer, feed, and agri–chemicals which are essential for the agricultural production. Second, the elasticities of demand for these variable inputs with respect to the output price are around 2.0, indicating that the demand for the variable inputs by the farm–firm are strongly influenced by changes in the output price. Finally, an increase in farm land increases the demand for these variable inputs fairly elastically.

At this point of the analysis, it is relevant to summarize our findings related to the estimates of the elasticities of the output supply and the demand for labor, fertilizer, feed, and agri–chemicals by the farm–firm. Farm–firms, at the microeconomic level, are very responsive to changes in the prices of output and variable inputs in their behavior of the supply of output and the demand for variable inputs. Furthermore, an increase in farm land plays an important role both in the output supply and the demand for variable inputs.

5. Summary and Conclusions

We analyzed the production behavior of the agricultural farm–firm for 1965 within the framework of the subjective equilibrium of the farm household. We employed the profit and factor demand functions approach for the empirical analysis of the production behavior of the farm household as a firm and estimated the profit, output supply, and factor demand functions.

Our empirical findings can be summarized as follows.

(1) The farm–firm maximizes its profit with respect to the farm–firm specific prices of labor, fertilizer, feed, and agri–chemical inputs. This implies that the farm–firm follows the marginal principles.

(2) There exist increasing returns to scale in agricultural production. This finding is consistent with the statistical trend that the number of larger scale farm households has been increasing while the number of smaller scale farm households has been decreasing during the postwar years in Japan.

(3) The numerical value of the supply elasticity with respect to the output price is about one. The farm–firm responds rather elastically to the output price in the supply of output. This finding indicates that there is no "rigidity of farm output supply" at the microeconomic level in the postwar agriculture.

(4) The farm–firm's demand for labor, fertilizer, feed, and agri–chemicals is elastic with respect to the respective own prices. Also, the farm–firm is highly responsive to changes in the price of output and it increases its demand for the variable inputs, and its supply of output in response to an increase in the output price.

(5) An increase in farm land plays an important role in increasing the demand for the variable inputs and the supply of output by the farm–firm as indicated by the relatively large elasticities, 0.73 for all cases.

At this point we would like to highlight specifically implications that arise from the introduction of prices, since this is a crucial feature of our analysis. The numerical values of the elasticities of the supply of farm output and of the demand for labor, fertilizer, feed, and agri–chemicals are high with respect to their own prices. Moreover, the demand for these variable inputs with respect to the output price is positive and elastic. This is evidence of the substantial market orientation of the Japanese farm–firm, and calls for framing price policies judiciously, if they are to be beneficial and effective. In line with the emphasis that the Japanese Government places on increasing the level of self–sufficiency through increased supplies of farm goods, price policies must be so designed as to provide strong incentives to farmers for increasing their output supply.

Emphasis has been placed in many quarters on structural changes that would increase the size of agricultural operations in Japan. Since land reclamation on a large scale is unlikely, this would imply consolidation in the number of small farms. We may consider the appropriateness of such policies in the light of our findings about the behavior of the farm household in production.

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Appendix A Definitions of the Variables in the Model

1. Quantity and Price of Output and Profit

The money profit, denoted by P', of the farm–firm is given by

$$P' = p_A Y - \sum_{i=1}^{4} q_1' X_i, \; i=1, 2, 3, 4, \tag{A-1}$$

where $p_A Y$ is the "value-added" in 1,000 yen, i. e., total output less variable costs other than labor, fertilizer, feed, and agri-chemicals, X_1 is the quantity of farm labor in man-days, q_1' is the money price of farm labor in 1,000 yen per man-day, X_2, X_3, and X_4, are the quantities of fertilizer, feed, and agri-chemicals in kgs., and q_2', q_3', and q_4' are the money prices of fertilizer, feed, and agrichemicals in 1,000 yen per kg., respectively. Our model requires the profit normalized by the output price: that is, we need $\Pi_a (\equiv P'/p_A)$. A number of operations are necessary for this purpose.

First of all, the output price should be farm-firm specific. This means that we should consider the fact that firms sell outputs at different times and in different markets and may therefore obtain different "average" prices, even in a regime where there are perfect markets. We need therefore to weight all these individual prices obtained in order to get the average price of output of each farm-firm. We consider that a geometrically weighted average price is the most relevant since it reflects the share of each product in the total production of a farm-firm.

Torii [1971] estimated the geometrically weighted average price of the farm products of an average farm-firm in each size class in each region for the period 1954–1967. We employed his estimates for 1965.

Before computing the normalized profit, $\Pi_a (\equiv P'/p_A)$, we will specify the quantities and prices of the variable factors of production in the following sections.

2. Quantity and Price of Farm Labor

The amount of labor expended on the farm (X_1) is defined as the sum of family labor (X_{1f}) and hired labor (X_{1h}). Hired labor consists of temporary and permanent hired labor. We assume the quality of labor in the two categories is homogeneous. Furthermore, family labor and hired labor are composed of male and female labor which may be different in quality. Therefore, we must homogenize the two different qualities of labor to justify the underlying assumption. Since NKCH reports the numbers of days per year spent on the farm for male and female workers separately, we converted female labor days to man-days by multiplying 0.8. The conversion coefficient, 0.8, is simply an average ratio of farm wage rate of female labor to that of male labor for the period 1963–1967. The data were taken from *Nōson Bukka Chingin Chōsa Hōkoku-Sho* (Survey Report on Prices and Wage Rates in Farm Villages).

Next, the farm specific price of labor was computed in the following manner. The total wage bill paid to both the permanent and temporary hired labor expressed in terms of 1,000 yen per year was divided by the total man-days of the hired labor. The necessary data were taken from NKCH. This price of labor, denoted by q_1', was imputed to the price of family labor in order to compute the total labor costs, $q_1' X_1$.

Finally, the normalized wage rate, q_1, was computed by dividing the money wage rate, q_1', by the output price, p_A.

3. Quantities and Prices of Fertilizer, Feed, and Agri-chemical

The 1965 NBT reports the total quantities of and the total expenditures on 17, 8 and 10 different kinds of fertilizer, feed, and agri-chemicals, respectively, per average farm-firm in each size class in each region. The quantities are given in terms of kilograms and the expenditures in terms of yen per year. The rest of the procedure of computing the average prices of these three variables follows the case of the output price. The prices are geometrically weighted average prices. The prices of fertilizer, feed, and agri-chemicals, q_2', q_3', and q_4', respectively are expressed in terms of 1,000 yen per kg. These prices were normalized by the output price to obtain q_2, q_3, and q_4, respectively, which are farm-firm specific.

Theoretically, the sums of the expenditures on fertilizer, feed, and agri-chemicals given in NBT should be equal to those given in NKCH for each corresponding farm-firm. However, the sums in NBT are usually smaller than those in NKCH. This is because NBT does not always cover every item for these variable inputs. Therefore, we employed the total expenditures on fertilizer, feed, and agri-chemicals reported in NKCH in order to compute the money profit(P') given in equation (A-1). Then, P' was deflated by the output price, p_A, in order to obtain the actual normalized profit, Π_a.

4. Machinery Capital, Plant Capital, and Animal Capital

We computed the flows of machinery, plant, and animal capital, denoted by K_1, K_2, and K_3 respectively, by the following formulae.

$$K_1 = M_m + D_m + 0.06K_m,$$
$$K_2 = D_p + 0.06K_p,$$
$$K_3 = M_a + D_a + 0.06K_a,$$

where K_m, K_p, and K_a are the stocks of these capital at the beginning of a crop year, in our case 1965. M_m and M_a are the costs of repairs and maintenance for machinery and the costs of insemination charges and maintenance for animals, respectively. D_m, D_p, and D_a are the depreciations of machinery, plant, and animal capital, respectively. The necessary data are all reported in NKCH per average farm-firm in each size class in each region. Finally, we applied on the expenditure for these items the interest rate of 6 percent, which was the average interest rate for one-year time deposits in commercial banks during the 1963-1967 period [12]. These service flows so obtained are farm-firm specific and are expressed in 1,000 yen.

5. Farm Land

One hectare of farm land in Tōhoku region may not be homogeneous with one hectare of farm land in Shikoku region. The former can only be used for single cropping while the latter is suitable for double- or triple- cropping. We need, therefore, to homogenize for differences in land quality among regions.

We assume that the price of farm land reflects land quality. The price of land in this context

12) The source of data for the interest rate is *Monthly Statistics of Japan* published by the Bureau of Statistics, Office of the Prime Minister.

is the rent in cash or in kind per unit of farm land. The farm land area multiplied by the rent per unit of land is defined as the service flow of the farm land. We therefore need the rent of farm land for each farm–firm. Unfortunately, the information on the farm rent specific to a farm–firm is not available. However, NKCH reports the total rent and the planted area of rented land per average farm–firm in each region. Therefore, we obtained the farm rent per unit of planted area of rented land by dividing the total rent paid by the total area of planted area of rented land per average farm–firm in each region. The service flow of farm land, denoted by K_4, was then computed for each farm–firm in each region by multiplying the total planted area by the farm rent per unit of planted area. K_4 is expressed in 1,000 yen per year.

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