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X-Inefficiency and Agricultural Productivity
in Postwar Japan

by

Yoshimi Kuroda

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1. Introduction

The objective of this study is to analyze quantitatively the effects of price support programs on farm-level productivity in postwar Japanese agriculture.

Prices of almost 80 percent of agricultural products including both crops and livestock have been supported by the Japanese Government directly or indirectly.^{1/} This has resulted in distortions in resource allocation not only in the agricultural sector but also in the overall Japanese economy. In particular, the fact that the producer price of rice has been fixed by the government at higher than the consumer price has led to some basic structural problems. First, the amount of funds necessary to fill the gap has been nearly one trillion yen (\$6.7 bil.)^{2/} per year on the average. This implies a tremendous amount of social welfare loss; as such the rice price support program has often been said to have functioned as transferring income to farmers. Furthermore, this large amount of deficit has pressed the total agricultural budget so as to substantially limit the amount of budget allocated for other important policies such as improving the structure of agricultural production.^{3/}

Another issue to be noted is that the rice price support program has applied to all rice-producing farmers, such that even marginal farm-firms have been able to continue rice farming. Lack of competition in production may be considered to have caused a certain measure of inefficiency where market feedback is considerably distorted due to the price support program.

Price support programs for other products, crops or livestock, may be considered to have had similar effects of limiting competition among farmers. These markets may be affected to lesser extent, however, since the prices of these products are not completely controlled by the government

as in the case of rice.

Studies of the effects of agricultural price support programs have been accumulating in the literature. There have been roughly two directions to such research. One is to evaluate the effects of price support programs on factor markets, especially labor and land. In this line of research, primary attention has been focused on quantitative evaluation of the effects of price support programs on labor migration from agriculture and on prices of labor and land (e.g., Schuh 1962, Floyd 1965, Gisser 1967 and 1971, Kuroda 1984, Masui 1984). Another direction of research has been in quantifying the effects of price support programs on social welfare through consumer's surplus analysis (e.g., Hayami 1972, Barker and Hayami 1976, Bale 1979, Bale and Greenshields 1978, Bale and Lutz 1981, Hayami, Subbarao, and Otsuka 1982, Otsuka and Hayami 1985).

As of yet, few studies can be found in the literature which analyze the impacts of price support programs on agricultural productivity. More specifically, as far as this author knows, there is almost no study which investigates quantitatively the impact of price support programs on growth of total factor productivity in agricultural production, which has a key relationship to overall agricultural sector growth. Accordingly, this study attempts to devise empirical methods toward understanding this problem.

It is hypothesized in this study that price support programs have caused "X-inefficiency" (Leibenstein 1976) in agricultural production and hence have had a certain negative effect on productivity in postwar Japanese agriculture. Let us elaborate on this hypothesis. Any price support program can be considered to have both positive and negative effects on production. If the price of an agricultural product is supported by the government, it follows that farmers are encouraged to produce

more of that product by increased and/or better use of resources, discovery and adoption of new agricultural technologies, and so on. However, if it turns out that the price support is maintained by the government for a considerably long period, farm management may face "slack" or "inert area" (in Leibenstein's [1976] terminology) due to lack of competition. Farm-firms may thus fail to minimize the average cost and/or to maximize profits due to such slackness. Such a failure in optimization of output is very likely to have a negative effect on agricultural productivity. Accordingly, the hypothesis in this study can be restated: the negative effects of price support programs have more than offset the positive effects on the growth in total factor productivity in postwar Japanese agriculture.

Furthermore, one may think of part-time farming as another source of X-inefficiency. Increased job opportunities in the nonagricultural sectors during the postwar years have resulted in a tremendous amount of transfer of labor out of agriculture. Even the heads of farm households and their eldest sons (who traditionally inherit the farms) have sought off-farm jobs. As a result, a great number of farms have become part-time farms — by the early 1980s, almost 90 percent of farm households were part-time farmers. This seems to have resulted in poorer quality of management, with such practices as weekend farming becoming prevalent especially in rice production.

The existence of this sort of easy-going or "slack" management can be considered as being intimately associated with price support programs. Because of the guarantee given by price support programs, part-time farms find it possible to continue farming in spite of the inefficient nature of their production. Such an indirect effect caused by price support programs

may also have played a significant role in suppressing overall agricultural productivity.

In order to test our hypothesis, the growth rate of total factor productivity (TFP) measured by the conventional Törnqvist approximations to the Divisia indexes will be decomposed into a number of effects. As is well known, assumptions underlying the conventionally-measured TFP growth rate are: (1) constant returns to scale; (2) cost minimizing behavior; and (3) marginal cost pricing of output. With these assumptions, the TFP growth rate coincides with the rate of technological change. Violations of these assumptions, therefore, discard this equality. In such cases, the TFP growth rate may be decomposed into (1) scale effect, (2) technological change effect, and (3) non-marginal cost pricing effect (Denny, Fuss, and Waverman 1981). In this study, all are covered, but a special focus is given to the last effect. A translog cost function framework is employed. It should be noted however that livestock production has grown very rapidly in postwar Japanese agriculture and become as equally important as rice production. Such changes in the output mix may have had significant impact on the elasticities of substitution, technological change, and scale economies.^{4/} Thus, in order to explicitly take into consideration the effects due to changes in the output mix on the technological structure of agricultural production, a multiple-product translog cost function will be specified and estimated by making use of aggregate farm-level data for the period 1958-84.

This study is organized as follows. In section two, the hypothesis is elaborated in a more formal fashion and a multiple-output translog cost function framework is introduced in order to test the hypothesis. In section three, the statistical method and data for the estimation of the

translog cost function are briefly discussed. Section four evaluates the empirical results by shedding special light on the effects of X-inefficiency on agricultural productivity. Finally, a policy implication based on the empirical results is provided as conclusion.

2. Methodology

To begin with, let us elaborate on the hypothesis exposed in the previous section in a more formal manner.

It is assumed that the farm-firm attempts to maximize profits. However, the process of profit maximization is divided into two stages. In the first stage, given the prices of factor inputs, the farm-firm minimizes total costs at a certain level of output. The farm-firm is therefore efficient in resource allocation at that level of output. Thus, X-inefficiency may not come out in this stage.^{5/}

In the second stage, the farm-firm is assumed to produce optimum output in order to maximize profits, given the minimum cost and the output price.^{6/} However, the farm-firm may fail to do so due to "slack" in management of agricultural production which is resulted from lack of competition due mainly to price support programs. Failures in optimizing output level imply non-maximization of profits and/or non-marginal cost pricing of output.

Thus, this study assumes that X-inefficiency occurs only in this stage of the optimizing behavior of the farm-firm. Furthermore, it is very likely that "slack" in farm management will cause farmers to produce less than optimal level of output. Double- or triple-croppings, and hence the rate of land utilization, have declined drastically during the last two

decades, and may be signs of such "slack".

Of course, there are other sources such as uncertainty and random errors by which the farm-firm may fail to maximize profits. If the farm-firm faces uncertainty, the level of output may be of less than optimum level. On the other hand, random errors might include factors which result in less-than-optimum output level. In either case, we may overestimate the effects of non-marginal cost pricing on agricultural productivity. However, since it is extremely troublesome to measure such effects due to uncertainty and/or random errors, this study assumes for simplicity that the effects of non-marginal cost pricing due to X-inefficiency overshadow those due to uncertainty and/or random errors.

In order to grasp visually the above verbal formulation, let us try to elucidate our hypothesis by help of a diagram. In this interpretation, we assume that all factor inputs are variable factor inputs, so that the production function of the representative firm is defined as one in the long run.

In Figure 1-a, isoquants Q^0 , Q^1 , and Q^2 touch the corresponding iso-cost lines at E^0 , E^1 , and E^2 , respectively. These iso-cost lines thus represent the long-run minimum total costs for given levels of output, Q^0 , Q^1 , and Q^2 , respectively. The minimum total cost for each output level can be measured by the intercept on the X_j axis, if it is evaluated in terms of factor input X_j . Thus, the intercepts, C^0 , C^1 , and C^2 represent the minimum total costs for the corresponding output levels, Q^0 , Q^1 , and Q^2 , respectively. If these intercepts are measured in terms of the price of X_j , the relationship between the quantities of output along the expansion path ^{//} and the corresponding minimum costs may be expressed by the total cost curve, LTC, as in Figure 1-c. Based on this

total cost curve, one can immediately derive the long-run average and marginal cost curves, LAC and LMC, respectively, as in Figure 1-c.

If the market of this product is perfectly competitive, the equilibrium price will be given by q^C which is tangent to the minimum of the long-run average cost curve (LAC) of the representative firm. The optimum level of output of this firm is then given by Q^0 . Suppose now that the government has decided to support the price of this product by setting it at q^S . Given this price level, if the firm attempts to maximize profits by equating the marginal cost of this output to the price, it will increase output level up to Q^1 . However, if the firm finds that the output price will always be supported by the government, it may take it easy and may not make enough efforts to maximize profits. In other words, "slack" or "inert area" in Leibenstein's terminology may manifest itself in the management of the firm. Under such a situation, two possible output levels can theoretically be considered; more than Q^1 , say, Q^2 and less than Q^1 . In the latter case, furthermore, we can subdivide into two areas. The first case is that the level of output is between Q^0 and Q^1 where LAC is increasing. The second possible output level is less than the long-run optimum level Q^0 where LAC is decreasing. In other words, the firm faces decreasing returns to scale in the former case, while it enjoys increasing returns to scale in the latter. Since there is empirical evidence for the existence of increasing returns to scale (Kako 1979, Chino 1984, Kuroda 1987b), we might assume that the actual level of output is given somewhere less than Q^0 , say, Q^A , in Figure 1-c. As clearly seen, at this level of output, the marginal cost is less than the price of output (q^S), obviously they are not equivalent, and the cost per unit of output is not minimized. This non-marginal cost

pricing (or non-profit-maximization) is hypothesized in this paper to have had negative effects on the growth of total factor productivity in postwar Japanese agriculture.

In order to investigate these effect quantitatively, the following multiple-output cost function is defined:^{8/}

$$(1) \quad C = g(Q_G, Q_A, P_L, P_M, P_I, P_T, P_O, t)$$

where C is the minimized cost; Q_G and Q_A are respectively the quantities of crop and livestock products; P_L , P_M , P_I , P_T , and P_O designate the prices of labor (X_L), machinery (X_M), intermediate inputs (X_I), land (X_T), and other inputs (X_O), respectively; and t is an annual index of time which is assumed to reflect technological change.

Totally differentiating the cost function (1) and the total cost $C = \sum_i P_i X_i$ ($i = L, M, I, T, O$) with respect to time and substituting the latter into the former, we obtain

$$(2) \quad -\dot{B} = \sum_j \varepsilon_{CQ_j} \dot{Q}_j - \dot{F}, \quad j = G, A,$$

where $\dot{B} \equiv (1/C) \partial g / \partial t$, the proportionate shift in the cost function (or the rate of cost diminution); $\varepsilon_{CQ_j} = (Q_j/C) \partial C / \partial Q_j$ = the cost elasticity of the j -th output ($j = G, A$); and $\dot{F} = \sum_i (P_i X_i / C) \dot{X}_i$ ($i = L, M, I, T, O$), the rate of growth of total inputs. Equation (2) shows that, if the growth rates of outputs and total input along with cost elasticities are given, one can calculate the negative of the rate of cost diminution due to technological change.

This negative of the rate of cost diminution ($-\dot{B}$) may be linked to the conventional measure of the growth rate of total factor productivity (TFP) as follows.

The rate of growth of total output is defined by

$$(3) \quad \dot{Q}^P = \sum_j \frac{q_j Q_j}{R} \dot{Q}_j$$

where $R = \sum_j q_j Q_j$, total revenue, and q_j is the price of the j -th output ($j = G, A$).

In order to allow for the possibility that the farm-firm may fail to equate the marginal costs to the prices of outputs, it is convenient to define the growth rate of total output by making use of cost elasticities, rather than revenue shares, as weights. That is,

$$(4) \quad \dot{Q}^C = \sum_j [\epsilon_{CQ_j} / \sum_j \epsilon_{CQ_j}] \dot{Q}_j = [\sum_j \epsilon_{CQ_j}]^{-1} [\sum_j \epsilon_{CQ_j} \dot{Q}_j]$$

Substituting (4) into (2), we obtain

$$(5) \quad \begin{aligned} -\dot{B} &= (\sum_j \epsilon_{CQ_j}) \dot{Q}^C - \dot{F} \\ &= (\sum_j \epsilon_{CQ_j} - 1) \dot{Q}^C + (\dot{Q}^C - \dot{Q}^P) + (\dot{Q}^P - \dot{F}) \end{aligned}$$

Using the conventionally-defined measure of the TFP growth rate, i.e., $\dot{TFP} = \dot{Q}^P - \dot{F}$, equation (5) can be rewritten as

$$(6) \quad \dot{TFP} = -\dot{B} + (1 - \sum_j \epsilon_{CQ_j}) \dot{Q}^C + (\dot{Q}^P - \dot{Q}^C), \quad j = G, A.$$

To see the economic meaning of $(\dot{Q}^P - \dot{Q}^C)$, suppose the farm-firm engages in marginal cost pricing. Then,

$$\epsilon_{CQ_j} = \frac{Q_j}{C} \frac{\partial C}{\partial Q_j} = \frac{q_j Q_j}{C}.$$

Therefore

$$\dot{Q}^C = \sum_j [q_j Q_j / \sum_j q_j Q_j] \dot{Q}_j = \sum_j [q_j Q_j / R] \dot{Q}_j = \dot{Q}^P.$$

Hence under marginal cost pricing $\dot{Q}^P = \dot{Q}^C$. If the farm-firm does not engage in marginal cost pricing, then $\dot{Q}^P - \dot{Q}^C \neq 0$. Thus, the term

$(\dot{Q}^P - \dot{Q}^C)$ in equation (6) measures the contribution of non-marginal cost pricing to the rate of growth of total factor productivity (TFP).

Thus, equation (6) states that the conventionally measured TFP can be decomposed into three effects: (1) a shift in the cost function (technological change), $-\dot{B}$; (2) a movement along the cost function (scale economies), $(1 - \sum_j \varepsilon_{CQ_j})\dot{Q}^C$; and (3) non-marginal cost pricing, $\dot{Q}^P - \dot{Q}^C$.

In the case of multiple-output cost functions, scale economies are defined as increasing, constant, or decreasing returns to scale according to whether $(1 - \sum_j \varepsilon_{CQ_j})$ is greater than, equal to, or less than zero (Fuss and Waverman 1981). Thus, if economies of scale are present, then TFP overestimates the rate of technological change ($-\dot{B}$) even if marginal cost pricing rules are used. However, if X-inefficiency is present in management of the farm-firm, we expect that the non-marginal cost pricing effect will contribute negatively to TFP, as interpreted diagrammatically in Figure 1.

In order to carry out decomposition analysis based on equation (6), we need estimates of the cost elasticities ε_{CQ_j} ($j = G, A$). For this purpose, we will estimate the multiple-output cost function specified as,

$$(7) \quad \ln C = \alpha_0 + \sum_j \alpha_j \ln Q_j + \sum_i \beta_i \ln P_i + \beta_t \ln t \\ + \frac{1}{2} \sum_{j,k} \gamma_{jk} \ln Q_j \ln Q_k + \frac{1}{2} \sum_{i,l} \delta_{il} \ln P_i \ln P_l \\ + \sum_{ji} \rho_{ji} \ln Q_j \ln P_i + \sum_j \mu_{jt} \ln Q_j \ln t \\ + \sum_i \nu_{it} \ln P_i \ln t + \frac{1}{2} \beta_{tt} (\ln t)^2,$$

$$j = k = G, A, \quad i = l = L, M, I, T, O,$$

where $\gamma_{jk} = \gamma_{kj}$ ($j \neq k$) and $\delta_{il} = \delta_{li}$ ($i \neq l$) due to the second-order

approximation property of the cost function.

Using Shephard's lemma, the cost-share equations can be obtained as

$$(8) \quad S_i = \beta_i + \sum_{\ell} \delta_{i\ell} \ln P_{\ell} + \sum_j \rho_{ji} \ln Q_j + v_{it} \ln t,$$

$$i = \ell = L, M, I, T, O, j = G, A.$$

Since the cost shares must add up to unity, $\sum_i S_i = 1$. This implies the constraints, $\sum_i \beta_i = 1$, $\sum_{\ell} \delta_{i\ell} = 0$, $\sum_j \rho_{ji} = 0$, and $\sum_i v_{it} = 0$ ($i = \ell = L, M, I, T, O, j = G, A$).

In the case of constant returns to scale and perfectly competitive conditions in output markets, Hall (1973) has suggested another set of behavioral equations, obtained by noting that marginal cost is equal to price. That is, logarithmic differentiation of the translog cost function (7) with respect to the quantities of outputs yields the "revenue" share equations of the form $\partial \ln C / \partial \ln Q_j = R_j$ ($j = G, A$). One could then estimate a system of the equations composed of the translog cost function, the cost share equations, and the revenue share equations. However, since the assumption of marginal cost pricing may be untenable due to the possible existence of X-inefficiency and indeed, where the objective of this study is in testing such an assumption, employing revenue share equations in our empirical estimations will be avoided.

Furthermore, we explicitly test the underlying assumption of cost-minimizing behavior in order to check its validity. This can be carried out by testing the equality of parameters appearing across equations (Christensen, Jorgenson, and Lau 1973). Results will have an important economic implication, since this test could be regarded as examining for the existence of X-inefficiency in resource allocation.

The cost elasticities ε_{CQ_j} ($j = G, A$) can be obtained once the

parameters of the multiple-output translog cost function (7) are estimated.

They are given by

$$(9) \quad \varepsilon_{CQ_j} = \frac{\partial \ln C}{\partial \ln Q_j} = \alpha_j + \sum_k \gamma_{jk} \ln Q_k + \sum_i \rho_{ji} \ln P_i + \mu_{jt} \ln t,$$

$$j = k = G, A, i = L, M, I, T, O.$$

Using the estimates of ε_{CQ_j} , \dot{Q}^C in equation (6) is obtained through the conventional Törnquist approximation procedure as

$$(10) \quad \Delta \ln Q^C = \frac{1}{2} \sum_j (c_{jt} + c_{jt-1}) \ln (Q_{jt}/Q_{jt-1})$$

where $c_{jt} = \varepsilon_{CQ_j} / \sum \varepsilon_{CQ_j}$.

With the information on ε_{CQ_j} and \dot{Q}^C together with the conventionally measured TFP and \dot{Q}^P , the rate of technological change (as defined as the negative of the rate of cost diminution), $-\dot{B}$, can be calculated residually based on equation (6).

3. Statistical Method and the Data

For the statistical estimation of the system of the translog cost function (7) and the cost share equations given in equation (8), the adding-up constraints are maintained. As is well known, these are essentially identical to the constraints of linear homogeneity in the prices of factor inputs on the cost function. We may then arbitrarily exclude any one equation from the five cost share equations in (8). We will thus omit the other-inputs cost share equation (S_0). The estimates of the coefficients of this equation can easily be obtained by making use of the parameter relationships of the adding-up constraints.

Rearranging the translog cost function and the four cost share equations by making use of the adding-up constraints yields a new system of the five equations. This system is then estimated as a simultaneous-equations system through the Iterative Seemingly Unrelated Regression (ISUR) method which is an improved version of Zellner's (1962) efficient estimation method (Oberhofer and Kmenta 1974).

The data required for the estimation of the model are the total cost (C), the quantities of crop and livestock products (Q_G and Q_A), and the prices (P_i) and cost shares (S_i) of the five factors of production, where i denotes labor (L), machinery (M), intermediate inputs (I), land (T), and other inputs (O). The major sources of data used to process these variables are the Survey Report on Farm Household Economy (FHE) and the Survey Report on Prices and Wages in Rural Villages (PWRV) published annually by the Japanese Government Ministry of Agriculture, Forestry, and Fisheries. For each year in the 1958-84 period one average farm was taken from each of the four size classes, 0.5-1.0, 1.0-1.5, 1.5-2.0, and 2.0 hectares or over (these represent all Japan excluding the Hokkaido district because of the different size classification). Thus, the sample size is $27 \times 4 = 108$.

As for data processing, the Törnqvist approximation procedure to the Divisia indexes was applied wherever possible. Since the detail of the variable processing is provided in Kuroda (1987a, 1987b), repetition is avoided in order to save space.

Instead, a word might be mentioned about the procedure of estimating the growth rates of total output (\dot{Q}^P), total input (\dot{F}), and total factor productivity (TFP). In this case also, the Törnqvist approximation procedure was extensively used, making use of the same data set as above.

However, one point to be noted is that these indexes and the growth rates are weighted averages; ratios of farm households in each of the above-mentioned four size classes as percentage shares of total number of farm households are used as weights. The estimated indexes of total output (Q^P), total inputs (F), and total factor productivity (TFP) for the 1958-84 period are presented in Appendix Table A-1.

4. Empirical Results^{9/}

To begin with, in order to check the goodness of fit of the model, the ordinary least-squares method was first applied. The estimated \bar{R}^2 are 0.998 for the translog cost function, and 0.937, 0.721, 0.643, and 0.891 for the four cost share equations, labor, machinery, intermediate inputs, land, and other inputs, respectively, indicating a fairly good fit of the model.

Next, the across-equations equality test was carried out in order to examine the validity of assuming cost-minimizing behavior in the process of the ISUR estimation. An F-test was conducted, and the computed F was 2.12 with the degrees of freedom (32,472). Since the critical F values with these degrees of freedom are 1.45 and 1.69 for the 1 and 5 percent significance levels, respectively, the hypothesis is rejected. However, since the rejection is not that definite, the assumption of cost-minimizing behavior could still be maintained as conceivable. Nevertheless, this result suggests that X-inefficiency might have existed in resource allocation in agricultural production. But, we will not investigate this problem further in this paper. Instead, we should note that, by imposing the parameter restrictions for cost minimization on the system of the five

estimating equations, estimates of the coefficients will be somewhat biased.

The estimates of the multiple-output translog cost function are reported in Appendix Table A-2. Monotonicity and concavity as regularity conditions were checked for each observation and were satisfied for all observations except for two. This indicates that the translog function represented by the estimated parameters in Table A-2 is well-behaved within the region of sample observations.

Decomposition of the Conventionally Measured TFP

To begin with, let us briefly investigate changes in growth rates of the conventionally measured total output, total input, and total factor productivity at the aggregate farm level during the 1958-84 period.^{10/} These growth rates can easily be obtained by making use of the indexes of total output, total input, and total factor productivity provided in Appendix Table A-1. For this computation, however, the twenty-seven year overall period 1958-84 was subdivided into two periods, 1958-75 and 1975-84. This subdivision was made by observing an apparent difference in the patterns of growth in total output between the two periods before and after 1975. Since the Japanese economy experienced the "oil crisis" in 1974, these two periods may be characterized as the before- and after-oil-crisis periods. Estimates of the annual average growth rates of total output, total input, and total factor productivity for these two periods and for the whole period are presented in Table 1.

According to Table 1, the annual average growth rate of total output for the overall 1958-84 period was 2.6 percent, while that of total input was 1.2 percent. Thus, the rate of growth of total factor productivity

for this period was 1.4 percent. These figures may indicate that the growth of agriculture was fairly moderate during the period under question. However, if a similar investigation is made over the two subperiods, a substantially different picture emerges.

The growth rate of total output during the 1958-75 period was as high as 4.2 percent per year which may be considered to be substantial for the agricultural sector. At the same time, total input and total factor productivity grew fairly rapidly — the annual growth rates were 2.0 and 2.2 percent, respectively. This seems to have been intimately related to the following facts: demand for agricultural products increased due to increased per capita income thanks to the rapid economic growth during this period. On the other hand, farmers introduced new production techniques such as machinery and chemicals in order to meet the increased demand for agricultural products.

During the 1975-84 period, however, the annual growth rate of total output became negative. The growth rate of total input also substantially declined compared with that in the previous period, and the growth rate of total factor productivity even became negative. This stagnation of agricultural production in the period after the oil crisis seems to have been strongly related to the decline in demand for agricultural products due to the decreased rate of increase in per capita income after the oil crisis.

At this point, let us look into the relative contribution of the growth rate of TFP to that of total output. During the overall 1958-84 period, the growth rate of total factor productivity accounted for 53 percent of the growth rate in total output. Investigating separately for the two subperiods, the contribution of the growth rate of TFP to

the growth rate of total output during the 1958-75 period was 52 percent, which is almost equal to that for the whole period. During the 1975-84 period, the (negative) growth rate of TFP also contributed substantially to the (negative) growth rate of total output. Or, we may say that mainly because of the strongly negative growth in total factor productivity, the growth of total output became negative during this period. In sum, we may conclude that the growth in total factor productivity played an important role in the determination of growth in aggregate agricultural production. Let us now look into the factors which determined growth rates in TFP during the period under question.

Making use of equation (6), the conventionally measured TFP was decomposed into the scale effect, non-marginal cost pricing effect, and technological change effect for the two subperiods, 1958-75 and 1975-84, as well as for the whole period 1958-84. In this computation, scale economies were obtained through equation (9); the cost elasticity weighted growth rate of total output (\dot{Q}^C) was estimated by equation (10); and the rate of technological change ($-B$) was obtained residually by subtracting the scale and non-marginal cost pricing effects from TFP. Furthermore, the percentage contributions of (1) the scale effect, $(1 - \sum_j \varepsilon_{CQ_j}) \dot{Q}_j$, (2) the non-marginal cost pricing effect, $\dot{Q}^P - \dot{Q}^C$, and (3) the technological change effect, $-B$, to the conventionally measured growth rate of total factor productivity, TFP, were computed. The results are provided in Table 2. Several important findings emerge from this table.

First of all, as we expected, the non-marginal cost pricing effect was found to be negative for the whole period as well as for the two subperiods. This substantially-negative effect, due to the departure from marginal cost pricing, may be considered to have been caused largely by

X-inefficiency, although it may include some bias. This is due to the cost minimization restrictions in estimation procedure for the translog cost function (in spite of the rejection of this maintained hypothesis). The direction of the bias is unknown. The negative effect due to non-marginal cost pricing found in this study is in contrast with the positive effect obtained by Denny, Fuss and Waverman [1981, Table 9, p.20] for Canadian telecommunications. This sharp contrast may suggest an interesting research topic, in the sense that the competitive nature of agriculture may be often spoiled by government interventions. Denny et. al analyze the behavior of a regulated industry which enjoys monopolistic power. In the former case, output prices are often supported by outside forces, while, in the latter case, output prices can often be internally controlled.

Another finding to be noted is that there existed substantial scale economies in agricultural production during the period under question. This implies that the level of production of aggregate outputs was quite-considerably less than optimal. Thus, efficiency gains resulting from scale economies were considerably large during the 1958-75 period (1.0 percent) but drastically declined during the 1975-84 period (0.1 percent) due to the drastic decrease in the growth rate of cost-elasticity weighted total output. These efficiency gains due to scale economies were completely (or more than completely) offset by the negative effects due to non-marginal cost pricing, however.

Finally, the technological change effect due to shifts in the cost curve was substantially large during the 1958-75 period. This seems to almost completely explain the growth rate of TFP, since the scale effect and non-marginal cost pricing effect offset each other. This large technological progress seems to have resulted from a considerable number

of innovations in agriculture, in both crop and livestock production. These might be characterized by rapid mechanization and increased use of chemicals during this period. This technological change effect became negative during the 1975-84 period, however. It was this negative technological change effect, together with the negative effect due to non-marginal cost pricing, which brought about the fairly significant negative growth rate in total factor productivity during this period.

Recall however that the estimates of the technological change effects in Table 2 were residually obtained, and therefore they suffer from any errors resulting from estimation of cost elasticities. However, we may measure technological change parametrically by making use of the estimated translog cost function. This allows us to quantify the rate of shift of the cost function (or the rate of cost diminution).

The parametric estimate of the rate of cost diminution (\dot{B}^*) is given by

$$(11) \quad \dot{B}^* = - \frac{\partial \ln \hat{C}}{\partial t} = \frac{-1}{t} \left(\hat{\beta}_t + \sum_j \hat{\mu}_{jt} \ln \dot{Q}_j + \sum_i \hat{v}_{it} \ln P_i + \hat{\beta}_{tt} \ln t \right),$$

$$j = G, A; i = L, M, I, T, O,$$

where $\hat{}$ designates the estimated values. This parametrically measured \dot{B}^* will differ from the residually determined measure, \dot{B} .

Thus, equation (6) may be rewritten as

$$(12) \quad \dot{TFP} = (1 - \sum_j \varepsilon_{CQ_j}) \dot{Q}^C + (\dot{Q}^P - \dot{Q}^C) + (-\dot{B}^*) + \text{Residual}.$$

Using equations (6) and (12), the relationship between $(-\dot{B})$ and $(-\dot{B}^*)$ is written as

$$(13) \quad -\dot{B} = -\dot{B}^* + \text{Residual}.$$

Based on equation (11), $-\dot{B}^*$ was estimated by making use of parameter estimates of the multiple-output translog cost function. A comparison

of residually and parametrically determined technological change is made in Table 3.

According to Table 3, for the overall 1958-84 period, both measures are almost equal. But in the two subperiods a different picture emerges. During the 1958-75 period, the residually determined rate of technological change was found to be slightly greater than the parametrically determined rate of technological change. The 1975-84 period was in sharp contrast, however. That is, the residual measure of the rate of technological change was -0.44 percent, whereas the parametric measure was 1.23 percent per year.

This difference may cause significant variation when drawing conclusions from the measured rate of technological change. If we stick to the residually determined rate of technological change (\dot{B}), we may say that there occurred technological retrogression in Japanese agriculture during the 1975-84 period. On the other hand, if we use the parametric measure of the rate of technological change, we will be lead to state that although the rate of technological change during the 1975-84 period slowed down somewhat compared with that during the 1958-74 period, there was still moderate technological progress even during the 1975-84 period, where the Japanese economy as a whole entered upon a stage of "stagnant" or low growth. Since the latter measure of the rate of technological change does not suffer from errors in the estimation of the cost elasticities (ϵ_{CQ_j}), we may regard it as a better estimate than the former measure. This finding of positive technological progress during the 1975-84 period seems to be supported by the fact that mechanization with larger-scale machinery (such as riding-type tractors, combines, and rice-transplanters) and new innovations in livestock production were promoted

during this period.

A possible alternative approach to analysis of the growth of total factor productivity is to measure the efficiency gains directly from the estimated translog cost function. Define

$$(14) \quad \dot{TFP}^* = \frac{d \ln \hat{C}}{dt} - \sum_i \hat{S}_i \dot{P}_i - \dot{Q}^C.$$

Total differentiation of $\ln \hat{C}$ with respect to time yields

$$(15) \quad \frac{d \ln \hat{C}}{dt} = \sum_j \hat{\epsilon}_{CQ_j} \dot{Q}_j + \sum_i \hat{S}_i \dot{P}_i + \frac{\partial \ln \hat{C}}{\partial t}.$$

Combining equation (14) and (15), we obtain

$$(16) \quad \dot{TFP}^* = (1 - \sum_j \epsilon_{CQ_j}) \dot{Q}^C + (-\dot{B}^*)$$

where $-\dot{B}^* = \partial \ln \hat{C} / \partial t$.

Finally, combining equations (12) and (16), we obtain the following relationship between \dot{TFP} and \dot{TFP}^* .

$$(17) \quad \dot{TFP} = \dot{TFP}^* + (\dot{Q}^P - \dot{Q}^C) + \text{Residual.}$$

or

$$(18) \quad \dot{TFP}^* = \dot{TFP} - (\dot{Q}^P - \dot{Q}^C) - \text{Residual.}$$

Hence, \dot{TFP}^* represents only estimated efficiency gains due to scale economies and technological change. In the estimation of \dot{TFP}^* , the effects due to non-marginal cost pricing and unexplained estimation error on the growth rate of total factor productivity are excluded.

We are now able to make a comparison, illustrated in Table 4, based on the relationship (17) between the conventionally and parametrically determined rates of growth of total factor productivity, \dot{TFP} and \dot{TFP}^* , respectively. In this table \dot{TFP}^* is found to be consistently greater

than TFP for the overall 1958-84 period. The difference, -0.90 , can be completely explained by the non-marginal cost pricing effect, -0.98 . If we investigate the estimates in Table 4 separately for the two subperiods, substantially different findings may be observed.

During the 1958-75 period, TFP was smaller than $\dot{\text{TFP}}^*$ by 0.69 percent. But this difference is more than completely explained by the negative non-marginal cost pricing effect. During the 1975-84 period, however, the rate of growth of parametrically measured total factor productivity became positive (1.29 percent), though much lower compared with that for the 1958-75 period. This seems to have been due to the positive technological change as shown in Table 3 (1.23 percent). On the other hand, the conventionally measured TFP growth rate was -1.16 percent. As we have shown, a large part of this negative growth rate is explained by the negative non-marginal cost pricing effect. Thus, a large part of the big difference between the two measures of TFP growth rates during this period seems to be explained by the difference in the residually and parametrically measured rates of technological change during the period under question. As argued earlier, it is very likely that there was positive growth in total factor productivity due to the efficiency gains resulting from technological progress.

Nevertheless, a special stress should be put on the consistently negative effect of non-marginal cost pricing on the growth of total factor productivity. That is this negative effect resulting from X-inefficiency due largely to price support programs by the government may be said to have negatively affected the growth of total factor productivity in postwar Japanese agriculture.

5. Conclusion

The policy implication of the empirical results of this study is clear. Agricultural price support programs should at least be modified so as to stimulate competition among producers in order to raise productivity in Japanese agriculture. Such modifications in price policies are expected to reduce the X-inefficiency which results from "slackness" in farm management due to farmer-indulging price support programs. It is also expected that such modifications or abandonment of price policies will stimulate the exploitation of economies of scale through competition so that agricultural production will be carried out closer to the optimum level.

The limitation of this study is the assumption of cost-minimizing behavior. Indeed, this maintained hypothesis was statistically rejected (though barely). The a priori restrictions of cost-minimization may have caused some bias in our results. And, this failure in cost-minimization might have been due partly to the existence of X-inefficiency in resource allocation by farm-firms. For such a situation, a different formulation of the model may be necessary. One direction for such a formulation has been suggested by Atkinson and Halvorson (1980) who introduced an operational assumption that the firm equate marginal cost of an output and/or the marginal productivity of an input to a certain proportion of the market price.

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Footnotes

- 1/ The proportions of agricultural products supported by government price policies were 61 (1960), 59 (1965), 73 (1970), 84 (1975), and 81 (1980) percent, respectively.
- 2/ The current exchange rate, roughly ¥150/\$1, was used in this translation.
- 3/ The proportions of budgets for price support programs to total agricultural budget were 23 (1960), 37 (1965), 44 (1970), 43 (1975), 25 (1980), and 24 (1984) percent, respectively.
- 4/ As the postwar effects of changes in output mix on the technology of agricultural production have been fully analyzed in Kuroda (1986), repetition will not be made in this study.
- 5/ There are a great number of studies in the literature which investigated allocative efficiency and/or technical efficiency through, use of the frontier production or cost function approach. For example, Gollop and Karlson (1978), Försund and Hjalmarsson (1979), Aigner, Lovell, and Schmidt (1977), Farrell (1957), Bailey and Malone (1970), Pitt and Lee (1981), Kopp and Diewert (1982), Schmidt and Lovell (1979), to name only a few.
- 6/ Note that the output price here is set by the government, and hence is not an equilibrium price through perfect competition. However, even under such a situation, we may think of profit-maximizing behavior of the farm-firm by assuming that it attempts to equate the marginal cost of output to the "effective" price (q^S) which is set higher than the equilibrium price (q^C) by a certain proportion, say, k .
- 7/ If the production technology is homothetic, the expansion path becomes a straight line from the origin.

8/ The following formulation draws heavily on Denny, Fuss, and Waverman (1981).

9/ In order to avoid a simultaneous equations bias due to the possible endogeneity of output levels in the system, introduction of instrumental variables may be useful (Antle and Crissman). Noting that input decisions should depend not on actual, realized output levels but on expected or planned levels of output, we estimated a supply function of the form

$$Q_{it} = F_i(P_G, P_A, P_L, P_M, P_I, P_T, P_O, t), \quad i = G, A,$$

specifying them with the translog form and using the same set of data described in the previous section. The fitted values (Q_G° and Q_A°) were then used as estimates of expected output levels in the translog cost function. These measures of expected output levels are exogenous and therefore the estimates of the translog cost function are free of simultaneous equations bias.

10/ A more detailed investigation of these growth rates for each size class is provided in Kuroda (1987b).

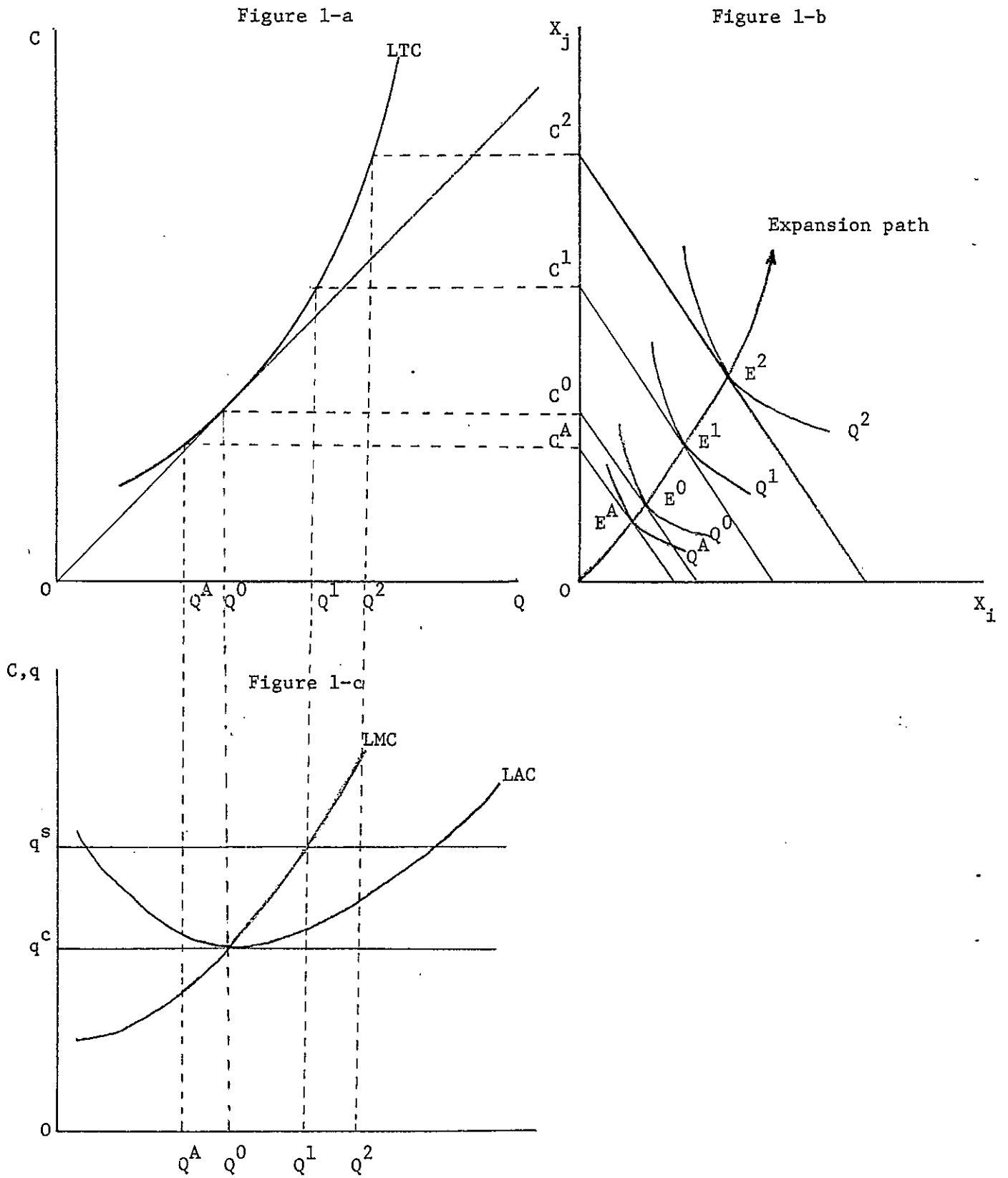


Figure 1. Cost Minimization and Cost Curves

Table 1. Annual Growth Rates of Conventionally Measured Total Output,
Total Input, and Total Factor Productivity, 1958-84

(unit:%)			
Period	\dot{Q}^P	\dot{F}	\dot{TFP}
1958-75	4.23 (100.0)	2.04 (48.2)	2.19 (51.8)
1975-84	-0.34 (100.0)	0.82 (-241.2)	-1.16 (341.2)
1958-84	2.62 (100.0)	1.23 (46.9)	1.39 (53.1)

Source: Table A-1.

- Note: 1) The average annual growth rate was computed by fitting $\ln y = a + gt$ where y is the Törnqvist index of total output or total input, t is an index of time, and a and g are parameters to be estimated.
- 2) \dot{TFP} was obtained residually by making use of the formula

$$\dot{TFP} = \dot{Q}^P - \dot{F}.$$
- 3) Figures in parentheses indicate the degrees of contribution to the growth rate of total output.

Table 2. Decomposition of the Rate of Growth of Total Factor Productivity, 1958-84

Period	\dot{Q}^P	\dot{Q}^C	Scale economies $(1 - \sum_j \epsilon_{CQ_j})$	Scale effect $(1 - \sum_j \epsilon_{CQ_j}) \dot{Q}_j$	Non-marginal		Technological change effect $-\dot{B}$	TFP
					cost pricing effect $\dot{Q}^P - \dot{Q}^C$	effect		
1958-75	4.23	5.22	0.191	1.00 (45.7)	-0.99 (-45.2)	2.18 (99.5)	2.19 (100.0)	
1975-84	-0.34	0.44	0.129	0.06 (-5.2)	-0.78 (67.2)	-0.44 (37.9)	-1.16 (100.0)	
1958-84	2.62	3.60	0.170	0.61 (43.9)	-0.98 (-70.5)	1.76 (126.6)	1.39 (100.0)	

Notes: 1) \dot{Q}^C was computed by making use of equation (10).

2) $-\dot{B}$ was obtained residually by subtracting the scale effect and non-marginal cost pricing effect from TFP.

3) Figures in parentheses indicate the degrees of contribution of scale effect, non-marginal cost pricing effect, and technological change effect to TFP.

Table 3. Comparison of Residually and Parametrically
Determined Technological Change ($-\dot{B}$ and $-\dot{B}^*$), 1958-84

(unit: %)

Period	(1) $-\dot{B}$	(2) $-\dot{B}^*$	(3) = (1) - (2) Residual
1958-75	2.18	1.88	0.30
1975-84	-0.44	1.23	-1.67
1958-84	1.76	1.68	0.08

Note: 1) $[-\dot{B}]$ is from Table 2.

2) $[-\dot{B}^*]$ was computed through equation (11).

Table 4. Comparison of Conventionally and Parametrically Determined
Rates of Growth of Total Factor Productivity, 1958-84

(unit: %)

Period	(1) TFP	(2) TFP*	(3) Difference (1) - (2)	(4) Non-marginal cost pricing effect $\dot{Q}^P - \dot{Q}^C$	(5) Residual (3) - (4)
1958-75	2.19	2.88	-0.69	-0.99	0.30
1975-84	-1.16	1.29	-2.45	-0.78	-1.67
1958-84	1.39	2.29	-0.90	-0.98	0.08

Notes: 1) TFP and $\dot{Q}^P - \dot{Q}^C$ are from Table 2.

2) TFP* was computed by equation (16).

Appendix Table A-1. Indexes of Total Output, Total Input, and
Total Factor Productivity, 1958-84

Year	Total output Q^P	Total input F	Total factor productivity TFP
1958	1.000	1.000	1.000
1959	1.043	1.032	1.010
1960	1.079	1.039	1.039
1961	1.109	1.065	1.042
1962	1.176	1.040	1.131
1963	1.217	1.106	1.100
1964	1.347	1.186	1.135
1965	1.357	1.220	1.112
1966	1.439	1.271	1.132
1967	1.487	1.303	1.141
1968	1.558	1.359	1.146
1969	1.567	1.379	1.135
1970	1.566	1.365	1.146
1971	1.653	1.311	1.260
1972	1.901	1.320	1.440
1973	1.921	1.316	1.460
1974	1.971	1.374	1.435
1975	2.020	1.368	1.476
1976	1.961	1.374	1.429
1977	1.917	1.322	1.452
1978	1.880	1.315	1.429
1979	1.848	1.330	1.387
1980	1.800	1.367	1.315
1981	1.860	1.426	1.302
1982	1.852	1.397	1.316
1983	1.923	1.430	1.336
1984	1.976	1.473	1.335

Note: Refer to text in section 3 for the sources of data and the computation procedures for these indexes.

Appendix Table A-2. Parameter Estimates of the Translog Cost Function

α_0	0.041**	δ_{TT}	0.050*	ρ_{GT}	0.043*
α_G	0.773*	δ_{OO}	0.007 ^o	ρ_{GO}	0.011 ^o
α_A	-0.068	δ_{LM}	-0.053*	ρ_{AL}	-0.032*
β_L	0.636*	δ_{LI}	0.009	ρ_{AM}	-0.018*
β_M	0.087*	δ_{LT}	-0.014**	ρ_{AI}	0.039*
β_I	0.169*	δ_{LO}	0.006 ^o	ρ_{AT}	-0.007
β_T	0.031*	δ_{MI}	-0.022*	ρ_{AO}	0.018 ^o
β_O	0.077 ^o	δ_{MT}	0.003	μ_{Gt}	-0.014**
β_t	0.053**	δ_{MO}	-0.0002 ^o	μ_{At}	0.125*
γ_{GG}	-0.141*	δ_{IT}	-0.027*	ν_{Lt}	-0.045*
γ_{AA}	0.087	δ_{IO}	-0.0007 ^o	ν_{Mt}	0.027*
γ_{GA}	-0.056	δ_{TO}	-0.012 ^o	ν_{It}	0.017*
δ_{LL}	0.051*	ρ_{GL}	-0.043*	ν_{Tt}	0.006
δ_{MM}	0.072*	ρ_{GM}	0.031*	ν_{Ot}	-0.005 ^o
δ_{II}	0.040*	ρ_{GI}	-0.019*	β_{tt}	-0.153*

Note: 1) * and ** indicate that the coefficients are statistically significant at the 5 and 10 percent levels, respectively.

2) Coefficients with o were obtained by making use of the adding-up parameter restrictions.