Journal of Rural Development 30(5): 19~37

THE CHARACTERISTICS OF TECHNOLOGICAL CHANGE IN RICE PRODUCTION IN KOREA

SHIM WOO HYUN*

Keywords

technological bias, technological change, technical change bias, translog cost function, Allen partial elasticities

Abstract

In general, technical progress is regarded as the most important factor in economic growth. However, in reality, many economic phenomena are influenced by technical change biases in addition to technical level.

The purpose of this paper is to empirically explore elasticities of substitution and technical change biases among factors of rice production in Korea. The main characteristic of Korean agriculture is land- and labor-intensive using. Hence the result of estimating elasticities of substitution and technical change biases may show a different result from the U.S. agriculture.

The result of Allen elasticities and technological change biases shows that the demand for labor will be decreased if the price of land is increased and increase in wages will cause increase in the use of machinery and fertilizer. It also shows that if the price of machinery increases, the use of fertilizer will be increased.

---

* Ph.D. Student, The Department of Telecommunication, Michigan State University, MI, U.S.

I. Introduction and Problem Statement

In general, technical progress is regarded as the most important factor in economic growth. However, in reality, many economic phenomena are influenced by technical change biases as well as the technical level. For example, employment level will be increased if the technology, which is labor-intensive, is continuously developed, and a country that has insufficient capital may need to import capital from other countries if it wants to choose the technology which is capital-intensive.

In this regard, Korean agriculture has the following characteristics: First, traditional farming has exerted a deep influence on Korean economic development and change. Rice, particularly, has maintained an important role in the Korean economy and has formed a unique part of Korean agriculture. Second, the market opening raised a sense of crisis in Korean agriculture since Korea’s entry into the WTO. The Korean government had set an enthusiastic goal of decreasing the production cost and tried to increase specialized full-time farmers and farming size, promote mechanization and cultivar development to support the goal. Third, Korean agriculture experienced many structural changes in recent years. The relative decrease in farm labor by the onrush of industrialization, the introduction of new agricultural techniques, and the dramatic increase in agricultural production had a great influence on Korea, which was based on traditional land- and labor-intensive agriculture. Fourth, the customer demand for organic products and the interest in environment-friendly agriculture has increased. Many farmers tried to decrease the use of pesticides and chemical fertilizers on land and cultivate agriculture organically. Fifth, land rent is continuously decreasing in compliance with the lack of agricultural labor, the forfeiture of the will to work on a farm, and the evasion of rural life. Sixth, the technological progress in Korean agriculture is mainly based on the increase in factor quantities rather than substitution effects.

Hence, the characteristics of technological changes in recent years might be different from the characteristics in past years. Recently, however, there is no study that estimates these technological change biases. From this point of view, it will be necessary to explore the recent characteristics of technical changes by estimating the elasticity of substitution and technical change biases for each input.

II. Key Research Gaps to Explore

In this chapter, previous researches which applied the approach using the translog cost function are reviewed across time in Korea and across nations.

In Korea, many researches using the translog cost function were conducted since it has many benefits in analysis. Lee (1982) studied technological change biases using time series data from 1965 to 1979. He argued that only technological change of land was neutral whereas other factors showed technological change biases. That is, labor and machinery displayed technology-saving biases, but other factors showed technology-using biases in his study. Kwon (1985) used time series data of rice production from 1964 and 1984 and stated that the technological change in rice production showed land neutral, labor-saving, and capital-using characteristics. Also, he argued that these technological changes can be well explained by relative price changes in factors, and land and fertilizer reacted to changes in other factor prices insensitively whereas machinery and labor are sensitive to changes in other factor prices. Heo (1986) argued that all factors were not neutral in technological change and showed land- and labor-saving biases and machinery-, fertilizer-, and pesticide-using biases in time series date from 1962 and 1984. The most recent study was conducted by Hwang (1995). In the study, he used time series data from 1966 to 1993 and argued that labor and land showed technology-saving biases whereas capital displayed technology-using biases in the result of Hicks neutrality of technological change.

There are also researches related to technological changes in other countries. Binswanger’s study(1974 b) based on state data of the United States showed complementarities in the labor-fertilizer pair, the machinery-fertilizer pair, and the land-other input pair. But only the complementarity of fertilizer and labor was significant. From this result, he argued that “less developed countries with unemployed labor might find an advantage in pushing fertilizer use if complementarity between fertilizer and labor is generally true across countries." He also claimed that machinery was a better substitute for land than for labor although the machinery-land elasticity was over-estimated to some extent and the best substitutes were land and fertilizer. Nghiep(1979) analyzed time series data from 1905 to 1938 in Japan. He tried to find causes of technical progress using translog cost function and develop interpretation which corresponds with a history of Japanese economy. He argued that, unlike Binswanger's research, there was complementarity between land and machinery.

As explained above, there is room for doubt whether the characteristics of technical change can be applied across time and countries. For example, as shown below in Table 1, there is no complementarity between fertilizer and labor in prewar Japanese agriculture. Also, many other partial elasticities of substitution show different signs and magnitudes.

From a biased technical change point of view, different results from Binswanger's research are also expected for other countries. For example, Binswanger's research shows very strong fertilizer and machinery using biases.

TABLE 1. Allen Partial Elasticities of Substitution estimated by different researchers

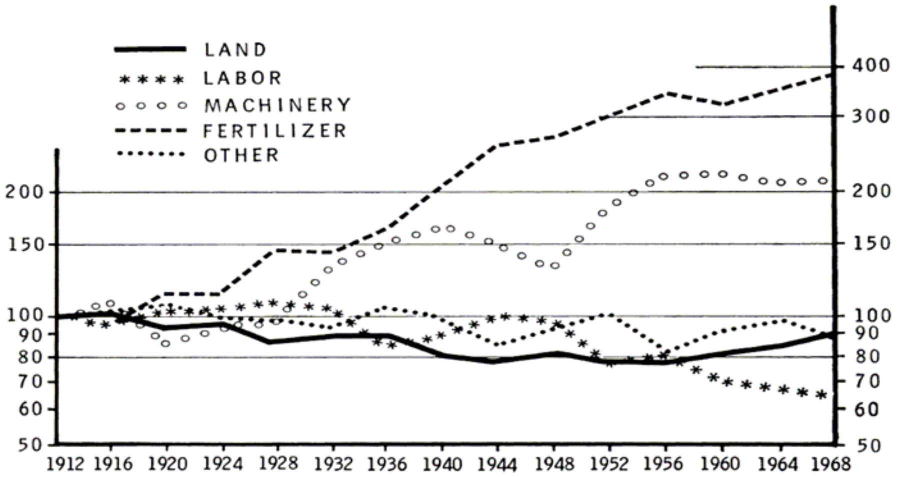
	Binswanger	Le Thanh Nghiep	Lee
Country	US	Japan	Korea
Data	1947~1964	1905~1938	1963~1980
Cost Function	Translog	Translog	Translog
Land-Labor	0.204	0.061	-0.147
Land-Fertilizer	2.987	-0.029	0.140
Land-Machinery	1.215	-0.859	0.603
Labor-Fertilizer	-1.622	0.230	0.698
Labor-Machinery	0.851	0.215	3.292
Fertilizer-Machinery	-0.672	-3.945	-1.956

Source: Binswanger, H. P., A Cost Function Approach to the Measurement of Factor Demand Elasticities and Elasticities of Substitution, A.J.A.E., 1974(a), 56, pp.377~386.

Nghiep, L. T, The Structure and Change of Technology in Prewar Japanese Agriculture, A.J.A.E., 1979, 61, pp. 687~693.

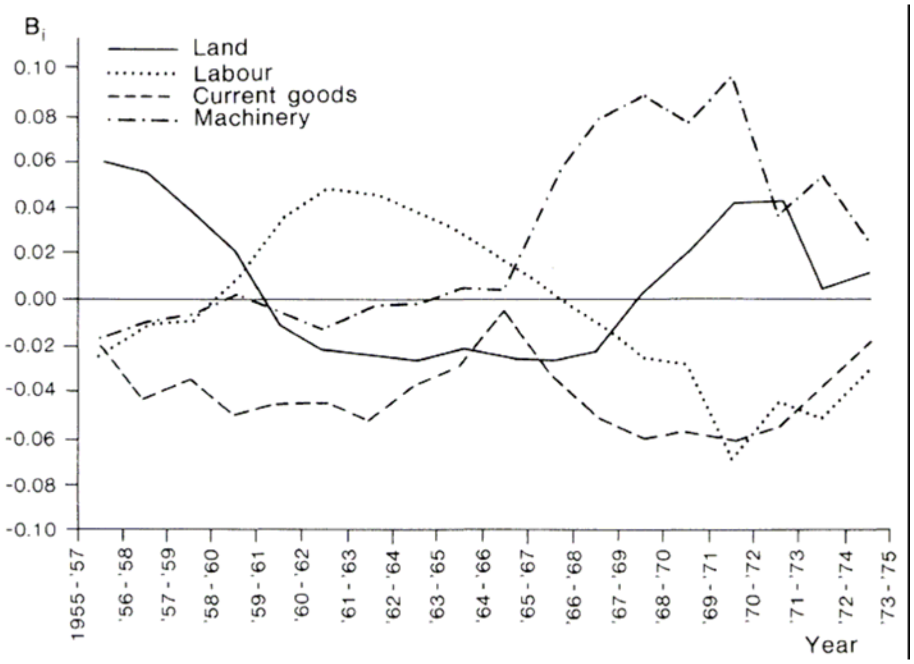
Lee, W. W., Characteristics of Technological Progress in Rice Production, Korea Rural Economic Review, 1982, 5(3).

FIGURE 1. Technical Change Biases in U.S. Agriculture



Source: Binswanger, H.P., The Measurement of Technical Change Biases with many Factors of Production, A.E.R. 1974(b), 64, p. 972

FIGURE 2. Technical Change Biases in Japanese Agriculture



Source: Lee, J. H., The Measurement and Sources of Technological Change Biases, with an Application to Postwar Japanese Agriculture, Economica, New Series, May 1983, 50 (198), p. 165.

However Lee's research (1983) displays a slightly different tendency of technical change biases for postwar Japanese agriculture, which shows strong fluctuation across the factors.

Since there is the gap in elasticities of substitution and measured biases of technical change across time in Korea and across countries, it will be well worth to find elasticities of substitution and technical change biases in Korea using recent data.

III. Objectives and Hypotheses

Since the turn of the 21st century, there is a universal understanding that intangible assets such as knowledge, information, and technology take the initiative of economic growth, rather than tangible production factors such as labor, capital, and land. Based on this point of view, it is necessary to estimate how much traditional production factors, such as land, labor and capital, contribute to the agricultural progress and to identify where the sources of agricultural progress are. The most general way to identify how much these tangible individual production factors contribute to the agricultural progress is by measuring the structure of agricultural production technology. In this context, measuring the structural change in agricultural production technology is very meaningful to build agricultural development strategies and develop appropriate agricultural policies. That is, by doing this study, we might be able to identify whether farmers in Korea use scarce resources effectively based on their circumstances and the government needs to design a more efficient market system that reflects the substitution of relatively abundant inputs for scarce inputs.

Hence this paper empirically explores elasticities of substitution and technological change biases empirically among factors for rice production in Korea to identify the structural changes among production factors, to analyze the influence of the changes in the relative price of factors on input ratio of factors, and to investigate whether structural changes in production reflect technical change biases and the rate of technological change well.

As mentioned in Chapter 1, the main characteristics of Korean agriculture are land- and labor-intensive, decrease in the use of farm labor, chemical fertilizers, and pesticides and increase in the use of machinery. Hence the result of estimating elasticities of substitution and technical change biases may show different results than U.S. agriculture. Hence the hypotheses are as follows:

1. The homogeneity condition and symmetric condition will be satisfied for most coefficients if a translog cost function is appropriately constructed.
2. Strong substitutability will exist between the land-machinery pair and labor- machinery pair, since machinery has a strong impact on technical progress. On the other hand, less strong substitutability is expected between the land-fertilizer and labor-fertilizer pairs since fertilizer can increase production without increasing land and labor. However there will not be substitutability between the fertilizer-machinery pair. Complementarity seems to exist between the land-labor pair since Korean agriculture uses labor- and land-intensive technologies.
3. For technical change biases, Korean agriculture will show very strong fertilizer- and machinery-using biases whereas labor- and land-using biases will be very low.

IV. Theoretical Framework

Agricultural production technology means the technological relationship between inputs and outputs, and technological change means that new production technology replaces existing technology to manage farms effectively or produce agricultural products efficiently. The technological change or technological progress can be distinguished by new input types and changes in input quality (Heady and Bail, 1972).

The technological relationships and the technological changes can be identified by technological parameters such as elasticities of substitution, economics of scale, and technological change biases. Since the technological relationships are determined by economic agents' technologies, the technological parameters can be estimated after choosing functional forms and estimating parameters of factors.

The general selection criteria for the product model are parsimony in parameters, ease of interpretation, computational ease, interpolative robustness, and extrapolative robustness(Fuss and McFadden, 1978).

Classically, production variables are classified by capital, labor, land, and other factors. In this paper, I regard the characteristics of technology of the production unit and aggregation issues as the most important criteria for distinguishing production variables since, in the selection procedure, variables should be determined by nature and not by the econometrician. From this point of view, production variables are categorized into five types: land, labor, machinery, fertilizer, and all others.

There are two ways to estimate elasticities of substitution and technological change biases for each input factor that occurred by technical change: using a production function or a cost function. However, a cost function has several advantages in estimating coefficients of factors and technological parameters compared to a production function. First, since the government's price regulation policy on agricultural products and yield regulation policy for balance of demand and supply interrupt marginal cost pricing, output levels should be treated exogenously. Second, to estimate the production function, the data for input and output quantities are needed and the variables that have several elements should be aggregated. However, since the data for input quantities are insufficient and difficult to aggregate, the corresponding dual cost function is better to use for solving this problem. Third, producers' optimization behavior is considered a maintained hypothesis in production function whereas producer's cost minimizing behavior is already included in realized cost data in cost function. Also, according to Binswanger (1974 a), in the case of the translog cost function, there are following advantages: first, "problems of neutral or non-neutral efficiency differences among observational units, or of neutral or non-neutral economies of scale, can be handled conveniently." Second, "all estimation equations are linear in logarithms." Hence, among several forms of cost function, a translog cost function which gives more benefit than others is used in this study to estimate elasticities of substitution and technical change biases.

The plan of the research paper is as follows: First, a translog cost function for rice production in Korea is discussed. Second, constraints such as homogeneous conditions and symmetry conditions are tested. Third, restricted generalized least squares(RGLS) is used to derive estimates of parameters. Fourth, a derivation of the partial elasticities of substitution in terms of the cross derivatives of the cost function is presented. Finally, technical change biases are measured based on Binswanger's amended version of Hicks neutrality.

V. Methods and Data

To estimate the translog cost function, data for Korean rice production between 1990 and 2004 are used. Fifteen sets of cross-sectional data were obtained from census data. The data is classified into 10 categories: below 0.5ha, 0.5~1.0ha, 1.0~1.5ha, 1.5~2.0ha, 2.0~2.5ha, 2.5~3.0ha, 3.0~5.0ha, 5.0~7.0ha, 8.0~10.0ha, and above 10.0 ha. Since this categorization is difficult to be used in the empirical research, I choose to use average values of the categories. For the farm size below 0.5ha and above 10.0ha, 0.25ha and 12.5ha will be used respectively.

As mentioned above, the following five factors are used in the research: land, labor, machinery, fertilizer, and all others.

To change each input price into a price index, the 1990 record is used as the base period, and the price of land where farm size is below 0.5ha is used as the base value. By using the price index, data can present the a series of actual factor shares and factor prices.

In this research, the following procedure, which is based on Binswanger's papers, will be applied to estimate partial elasticities of substitution and technical change biases.

Every production function has a minimum cost function as its dual which relates factor prices to the cost of the output. The cost function contains all the information about the production process which is included in the production function. The dual cost function which minimizes cost takes the form:

$$C = g(W_1, W_2, ..., W_n, Y, T_e) \quad \Lambda\,\Lambda\,\Lambda\,\Lambda \quad (1)$$

where C : minimum cost function
W_i : the price of each input
Y : output
T_e : technology level

In this study, technology level T_e is replaced by time variable T as a substituted variable and the cost function is specified as a translog form:

$$\ln C = \gamma_0 + \gamma_Y \ln Y + \gamma_{YY} (\ln Y)^2 + \gamma_T \ln T + \gamma_{TT} (\ln T)^2 + \sum_{i=1}^{n} \gamma_i \ln W_i$$
$$+ \frac{1}{2} \sum_{i=1}^{n} \sum_{j=1}^{n} \gamma_{ij} \ln W_i \ln W_j + \sum_{i=1}^{n} \gamma_{iT} \ln W_i \ln T \quad \Lambda\,\Lambda\,\Lambda\,\Lambda \quad (2)$$

In Binswanger’s original research(1974 b), he uses h(*Y*), which is a scale function of output, rather than the function

$$\gamma_Y \ln Y + \sum_{i=1}^{n} \gamma_{iY} \ln W_i \ln Y + \gamma_{\mathrm{YT}} \ln Y \ln T$$

in (2). However, in this paper,

$$\gamma_Y \ln Y + \sum_{i=1}^{n} \gamma_{iY} \ln W_i \ln Y + \gamma_{\mathrm{YT}} \ln Y \ln T$$

will be used to make the empirical study feasible.

I assumed that the cost function of specification (2) is well behaved so that it is homogeneous of degree one in input prices. Hence, to satisfy the homogeneity condition in input prices, the following constraints are defined:

$$\sum_i \gamma_i = 1, \quad \sum_i \gamma_{ij} = 0, \quad \sum_j \gamma_{ij} = 0, \quad \sum_i \gamma_{iY} = 0, \quad \sum_i \gamma_{iT} = 0 \quad \Lambda\,\Lambda\,\Lambda\,\Lambda \quad (3)$$

Also, the following symmetry constraint is imposed:

$$\gamma_{ij} = \gamma_{ji} \quad \Lambda\,\Lambda\,\Lambda\,\Lambda \quad (4)$$

By Shephard's lemma,

$$\frac{\partial \ln C}{\partial \ln W_i} = \frac{\partial C}{\partial W_i}\frac{W_i}{C} = \frac{x_i W_i}{C} = S_i \quad \Lambda\,\Lambda\,\Lambda\,\Lambda \quad (5)$$

where S_i is share of total cost accruing to input i. From this lemma, we derived the share equation for input i[2]:

$$S_i = \frac{\partial \ln C}{\partial \ln W_i} = \gamma_i + \sum_j \gamma_{ij} \ln W_j + \gamma_{iT} \ln T \quad \Lambda\,\Lambda\,\Lambda\,\Lambda \quad (6)$$

Hence if we calculate the coefficient of each independent variable based on the cost share of each input which is a dependent variable, and the price of each input and time variable which are independent variables, we can find the technological change bias and the elasticity of substitution for each input. Since inputs are classified into five categories, equation (6) can be written in following matrix form:

$$\begin{bmatrix} S_1 \\ S_2 \\ S_3 \\ S_4 \\ S_5 \end{bmatrix} = \begin{bmatrix} \gamma_1 \\ \gamma_2 \\ \gamma_3 \\ \gamma_4 \\ \gamma_5 \end{bmatrix} + \begin{bmatrix} \gamma_{11} & \gamma_{12} & \gamma_{13} & \gamma_{14} & \gamma_{15} \\ \gamma_{21} & \gamma_{22} & \gamma_{23} & \gamma_{24} & \gamma_{25} \\ \gamma_{31} & \gamma_{32} & \gamma_{33} & \gamma_{34} & \gamma_{35} \\ \gamma_{41} & \gamma_{42} & \gamma_{43} & \gamma_{44} & \gamma_{45} \\ \gamma_{51} & \gamma_{52} & \gamma_{53} & \gamma_{54} & \gamma_{55} \end{bmatrix} \begin{bmatrix} \ln W_1 \\ \ln W_2 \\ \ln W_3 \\ \ln W_4 \\ \ln W_5 \end{bmatrix} + \begin{bmatrix} \gamma_{1T} \ln T \\ \gamma_{2T} \ln T \\ \gamma_{3T} \ln T \\ \gamma_{4T} \ln T \\ \gamma_{5T} \ln T \end{bmatrix} \quad \Lambda\,\Lambda\,\Lambda\,\Lambda \quad (7)$$

where S_i is share of total cost accruing to input i, γ_i, γ_{ij}, and γ_{iT} are parameters, and T is time variable which is 1 if year is 1990, 2 if year is 1991, and so on. Subscripts 1, 2, 3, 4, and 5 represent land, labor, fertilizer, machinery, and others respectively. Each coefficient should satisfy constraints (3) and (4). Before estimating parameters, tests should be executed whether symmetry con-

---

[2] In this study, homothetic production function is assumed. This means: $\gamma_{iY} = 0$ (i= 1⋯n)

dition and homogeneity conditions are satisfied. If the symmetry constraint is satisfied, each farm acts from a cost minimizing sense. The homogeneity constraints are the general characteristic of cost function.

When we estimate each coefficient, we need to take into account that each cost share equation is linearly dependent since the sum of all cost shares equals to one and $\sum_i \gamma_{ij}$ and $\sum_j \gamma_{ij}$ equal to zero. That is, if the parameters of four cost share equations are estimated, the rest is assigned automatically. In this study, S_5, which represents others, will be removed since the characteristics of others which are the collection of various inputs are most unclear compared to other inputs.

Even if we choose four cost share equations, the parameters of the equations can not be estimated by OLS efficiently. Binswanger (1974 a, p. 381) indicates that "the combination of cross-sections over time poses problems ⋯ the error terms of the $n-1$ estimation equations are not independent, since for each state the same variables, which might affect the shares in addition to the prices, were left out of the model. If restrictions across equations ($\gamma_{ij}=\gamma_{ji}$) are imposed, OLS estimators are no longer efficient despite the fact that all equations contain the same explanatory variables on the right-hand side. Therefore, the seemingly unrelated regression (SUR) problem applies and restricted generalized least squares (RGLS) have to be applied to all equations simultaneously." Due to this reason, SUR and RGLS will be used in this study.

After estimating coefficients of cost function, we can identify the relationship between the factors by estimating partial elasticities of substitution. According to Allen (1938), partial elasticity of substitution for a cost function can be defined as follows:

$$\sigma_{\mathrm{ij}} = \frac{\sum \mathrm{W_i} x_i}{x_i x_j} \times \frac{\partial^2 C}{\partial W_i \partial W_j} = \frac{\mathrm{C} \times \mathrm{C_{ij}}}{\mathrm{C_i} \times C_j} \quad \Lambda\,\Lambda\,\Lambda\,\Lambda \quad (7)$$

where C : minimum cost function

$\mathrm{x_i}$, $\mathrm{x_j}$: input factors

$\mathrm{C_i} : \frac{\partial C}{\partial W_i}$

$\mathrm{C_{ij}} : \frac{\partial^2 C}{\partial W_i \partial W_j}$

The Allen partial elasticity of substitution shows the extent to which farms alter the usage of two inputs as input prices change. The Allen partial elasticity of substitution is widely used since this is relatively easy to estimate and understand the relationship pairs of all factors.

If a translog cost function is used, partial elasticities of substitution can be written:

$$\sigma_{ij} = \frac{\gamma_{ij}}{S_i S_j} + 1 \quad \Lambda\,\Lambda\,\Lambda\,\Lambda \quad (8)$$

$$\sigma_{ii} = \frac{1}{S_i^2}(\gamma_{ii} + S_i^2 - S_i) \quad \Lambda\,\Lambda\,\Lambda\,\Lambda \quad (9)$$

where γ_{ii}, γ_{ij} : *coefficients* of translog cost function

S_i, S_j : cost shares of factor i and factor j

There is substitutability between factors if the sign of elasticity of substitution is positive, and there is complementarity between factors if the sign of elasticity of substitution is negative.

The basic estimation equation for the technological change biases can be described:

$$dS_i^* = dS_i - \sum_{j=1}^{n} \gamma_{ij} d \ln W_j \quad \Lambda\,\Lambda\,\Lambda\,\Lambda \quad (10)$$

$$S_{it}^* = S_{i,1991} + \sum_{\text{T}=1991}^{\text{t}} dS_{it}^* \quad \Lambda\,\Lambda\,\Lambda\,\Lambda \quad (11)$$

$$\text{Q}_\text{i} = \frac{S_{it}^*}{S_{i,1991}} \quad \Lambda\,\Lambda\,\Lambda\,\Lambda \quad (12)$$

[3]

where the dS_i^* is the change in the factor share of input *i* in the absence of ordinary factor substitution due to price changes; dS_i is the actual total change in share *i*, which includes the effect of the price changes; $d \ln W_j$ is the proportional change of the ratio of the price of factor *i* to the price of other inputs;

---

[3] In actual estimation of technological change biases, three-year moving averages of the shares and the factor prices were used since it is assumed that the data had no observable trend. Also, the factor share in year *T* as the average factor share over the most recent years can reflect the reality more appropriately. Hence 15 years of data will decrease by 12 years of data.

S^{*}_{it} is the share of factor *i* in year *t* with respect to the share of factor *i* in 1991; Q_i is technical change bias of factor *i* in year *t*. For example, if technical change bias for land has a negative value, this implies that there is land-saving technical change (Binswanger, 1974 b).

VI. Discussion of Results

Before estimating the coefficients of factors, symmetry and homogeneous constraints need to be tested. In the constraints, three homogeneous constraints were rejected at the 5% significant level. Hence, homogeneity and symmetry were imposed in the model.

Table 2 displays the estimates of the coefficients of cost function. The values in the parenthesis are t-values of the price coefficient. Some coefficients are not significant as shown in the table. One implication can be made about the coefficients of time. In the land, labor, and other equations, the coefficients of time are significant. This implies that technological change has been land-using, labor- and other-saving.

TABLE 2. Estimates of the Coefficients of the Translog Cost Function

	Independent Variables						
Factor	Land	Labor	Machinery	Fertilizer	Other	Year	Intercept
Land	0.0420	-0.1890	-0.0419	0.0042	0.0408	0.0762	0.2405
	(2.15)	(-19.15)	(-4.24)	(1.05)	(4.30)	(10.64)	(2.93)
Labor		0.0681	0.0065	0.0113	-0.0024	-0.0264	1.1774
		(3.07)	(1.38)	(1.94)	(-0.20)	(-2.93)	(23.28)
Machinery			0.0520	-0.0020	-0.0090	-0.0015	0.2727
			(8.42)	(-1.08)	(-2.02)	(-0.49)	(6.64)
Fertilizer				0.0098	-0.0080	-0.0017	0.0665
		Symmetric		(3.76)	(-1.84)	(-0.70)	(3.13)
Other					0.1158	-0.0258	-0.2112
					(8.72)	(-5.63)	(-4.94)

After calculating each coefficient of translog cost function, each factor share can be calculated using equation (6). Table 3 displays unweighted average factor shares in the period 1990-2004.

TABLE 3. Unweighted Average Factor Shares: 1990-2004

	Land	Fertilizer	Machinery	Labor	Other
Factor Share	0.461	0.044	0.140	0.241	0.115

Using these factor shares, estimates of coefficients can be converted into Allen partial elasticities of substitution. From the equation (8) and (9), the estimates of Allen partial elasticities of substitution are calculated as shown in table 4. Own demand elasticity of other has incorrect sign since the sign is positive. There are several things we should look into. First, there are complementary relationships in land-labor pair and fertilizer-other pair. For instance, since the sign of land-labor is negative, the demand for labor will be decreased if the price of land is increased. Second, there are substitutional relationships in land-fertilizer pair, labor-fertilizer pair, labor-machinery pair, land-other pair, machinery-fertilizer pair and labor-other pair. It should be noted that, differently from my hypothesis, machinery-fertilizer pair has a substitutional relationship, and hence farmers will use more machinery if the relative price of fertilizer is increased.

TABLE 4. Estimates of Allen Partial Elasticities of Substitution

	Land	Labor	Machinery	Fertilizer	Other
Land	-0.9734	-0.7068	0.3504	1.2098	1.7704
Labor		-1.9803	1.1917	2.0684	0.9122
Machinery			-3.4898	0.6668	0.4429
Fertilizer		Symmetric		-16.6934	-0.5863
Other					1.0649

To find technological change biases, dS_i^* is estimated using three year moving averages of the shares and the factor prices, since the share and factor price in year *T*, which is the average factor share over the most recent years (average of year T-1, T, and T+1), can reflect the reality more appropriately. By this reason, 15 years of data decrease by 12 years of data. Table 5 shows

dS_i^*.

TABLE 5. Change in the Share of Factor i in the Absence of Ordinary Factor Substitution due to Price Changes

Year	dS_l*	dS_f*	dS_m*	dS_{la}*	dS_o*
1992	0.022	0.000	0.002	-0.004	-0.017
1993	0.003	-0.001	0.005	-0.013	0.002
1994	0.006	-0.001	0.004	-0.007	0.000
1995	0.019	-0.003	0.003	-0.004	-0.007
1996	0.029	-0.002	-0.008	-0.002	-0.006
1997	0.017	0.000	-0.005	-0.001	-0.006
1998	0.010	0.002	-0.003	-0.003	-0.004
1999	0.006	0.001	0.002	-0.003	-0.005
2000	-0.002	0.000	0.009	-0.005	-0.004
2001	0.004	0.001	0.003	-0.005	-0.001
2002	0.012	0.001	-0.002	-0.005	0.000
2003	0.025	0.001	-0.018	-0.006	0.004

As shown in Table 6, S_{it}^* can be estimated using the values in table 5.

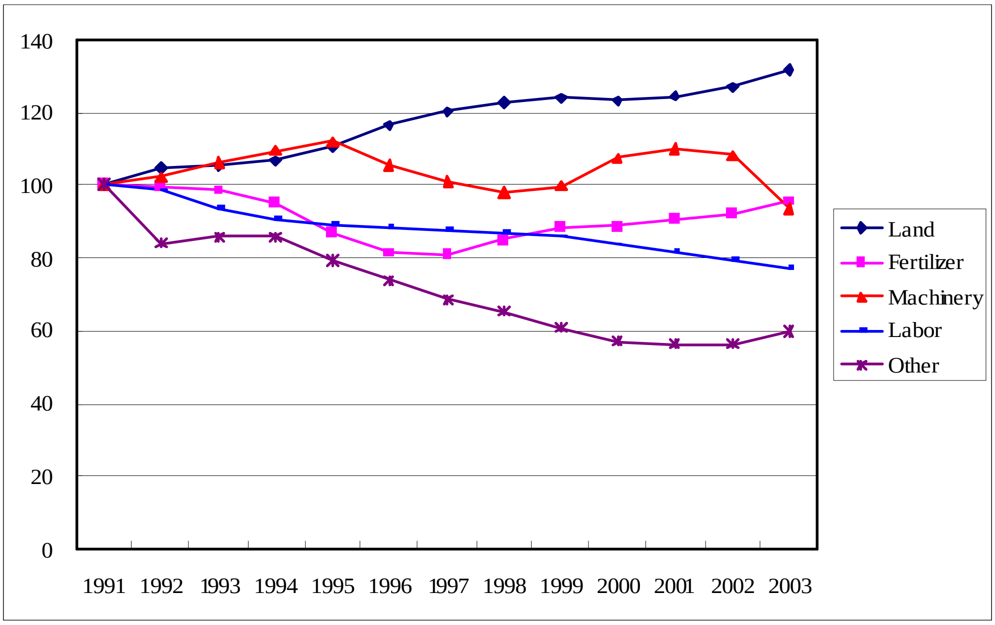
TABLE 6. The Share of Factor i in Year t with respect to the Share of Factor i in 1991

Year	S_{lt}*	S_{ft}*	S_{mt}*	S_{lat}*	S_{ot}*
1991	0.47	0.04	0.12	0.26	0.11
1992	0.49	0.04	0.12	0.25	0.09
1993	0.50	0.04	0.13	0.24	0.09
1994	0.50	0.04	0.13	0.23	0.09
1995	0.52	0.03	0.14	0.23	0.09
1996	0.55	0.03	0.13	0.23	0.08
1997	0.57	0.03	0.12	0.23	0.07
1998	0.58	0.03	0.12	0.22	0.07
1999	0.58	0.04	0.12	0.22	0.07
2000	0.58	0.04	0.13	0.22	0.06
2001	0.59	0.04	0.13	0.21	0.06
2002	0.60	0.04	0.13	0.21	0.06
2003	0.62	0.04	0.11	0.20	0.07

* $S_{i,1991}$ for each factor share is same as the value in 1991.

Now, using equation (12), technological change biases can be estimated as illustrated in Figure 3. Labor and other show technology saving overall years whereas land displays technology using. The use of fertilizer decreases until 1996 and increases after then, and the use of machinery fluctuates strongly and this may be partly because of troubled economics. Hence fertilizer and machinery can be regarded as technology-neutral.

FIGURE 3. Indices of Technological Change Biases



VII. Conclusion

From the results of Allen elasticities of substitution and technological change biases, we can infer followings: First, since the sign of land-labor is negative, the demand for labor will be decreased if the price of land is increased. This indicates that farmers may leave the farm or try to use more other factors instead of decreasing labor if land rent is increased. Second, labor-machinery and labor-fertilizer pairs show a relatively strong substitutional relationship.

Hence, any increase in wages will causean increase in the use of machinery and fertilizer. Third, if the price of machinery increases, the use of fertilizer will be increased since the Allen elasticity of substitution is positive.

For technical change biases, the following implications will be possible: First, land displays technology-using, and one of the reasons for land-using technology may be decrease in land rent. This result is very interesting since Korean agriculture has used land-intensive technology. Second, labor shows technology-saving because of high increase in wage and decrease in farm labor. Third, machinery exhibits a technology-neutral tendency. This might be because of troubled economics and currency crisis in 1997. Fourth, this machinery-saving tendency might influence the use of fertilizer since they are substitutions.

Technological change influences the use of inputs in a number of ways. Increasing productivity may require less input in some production variables, but more input in other production variables. As shown in the result of this study, rice production in Korea seems to follow this trend: land-using, labor-saving, machinery-neutral. To sustain progress in agricultural production, however, it should be noted that facilitating the substitution of relatively abundant variables for scarce variables is necessary.

Consequently, to expedite the agricultural development and cope with the rapidly changing circumstances, the agricultural policy must include effective designs for developing an efficient market system that makes it possible to substitute relatively abundant variables for scarce variables in accordance with market prices.

REFERENCES

Allen, R. G. D. 1938. Mathematical Analysis for Economists, London, Macmillan.

Binswanger, H. P. 1974. A Cost Function Approach to the Measurement of Factor Demand Elasticities and Elasticities of Substitution, American Journal of Agricultural Economics, 56 (a), pp.377-386.

______. 1974. The Measurement of Technical Change Biases with Many Factors of Production, American Economic Review. 64 (b), pp. 964-976.

Fuss, M. and D. McFadden. 1978. “Production Economics: A Dual Approach to Theory and Applications.” North-Holland, pp. 224-225.

Heady, E. O., and A. G. Bail. 1972. “Size, Structure and Future of Farms.” Iowa State University, Ames: Iowa State University Press, pp. 235-240.

Heo, S. H. 1986. The Status Quo and Perspectives of Korean Agriculture, A Series of Korea Rural Economic Review, 17.

Hwang, C. Y. 1995. An Analysis of Changes in Production Technology in Korean Agriculture, Master Thesis, Korea University.

Kwon, T. J. 1985. A Study of Economies of Scale in Rice Production, Master Thesis, Seoul National University.

Lee, J. H. May 1983. “The Measurement and Sources of Technological Change Biases, with an Application to Postwar Japanese Agriculture.” Economica, New Series, 50 (198), pp. 159-173.

Lee, W. W. 1982. Characteristics of Technological Progress in Rice Production, Korea Rural Economic Review, 5(3)

Nghiep, L. T. 1979. The Structure and Changes of Technology in Prewar Japanese Agriculture, American Journal of Agricultural Economics, 61, pp. 687-693

Cross-sectional data for Korean rice production between 1990 and 2004 form Korean Statistical Information System. <http://kosis.nso.go.kr/>.