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TECHNICAL CHANGE AND ELASTICITY OF FACTOR DEMAND IN RICE PRODUCTION IN BANGLADESH

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ABSTRACT

The study was undertaken with a view to finding the technical change in agriculture and factor demand status of the rice crop of Bangladesh. The production technology of the farmers was represented by the translogarithmic cost function. The data were collected from secondary sources. The findings revealed that there was a complementary relationship between the human labor and bullock labor, bullock labor and fertilizer, seeds and fertilizer, seeds and irrigation and fertilizer and irrigation. However, substitutory relationship was observed between human labor and irrigation, human labor and seeds, human labor and fertilizer, bullock labor and seeds and bullock labor and irrigation. The own and cross price elasticities of factor demand were all inelastic indicating that farmers response to changes in the price of inputs were small in magnitude. Rice production technology of Bangladesh appeared to be both labor and capital intensive. This situation may be treated as a transition to the modernization of agriculture.

I. INTRODUCTION

From time immemorial the agricultural sector of Bangladesh is characterized by small farms. Area operated per farm household is approximately 2 acres and per capita cultivated land is 0.25 acre. Access to institutional credit are highly limited to the small farmers. Most beneficiaries of institutional credit are large farmers who are capable of influencing and meetting the collateral requirement of the institutional credit. Most of the land preparation and some phases of harvesting activity are done by the animal power and human labor. Use of tractors and other forms of mechanical power were very limited during the pre liberation period. There was little use of HYV sseds, fertilizer, pesticides and irrigation water in that period.

Bangladesh agriculture has achieved a fairly fast growth rate during the period of 1970's (Parthasarathy and Chowdhury, 1988). It could be postulated that the agricultural growth of Bangladesh was made possible by dynamic substitution between primary inputs such as land, labor, and technical inputs such as improved seeds, chemical fertilizers, and irrigation. Without the substitution of modern inputs for traditional inputs the growth rate of agriculture

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might have been quite different. In this sense, study on factor substitution is an important area that requires in depth investigation. Of further importance is the status of demand for factors of rice production over time and nature of technical change taken place among different inputs. A good number of studies (Binswanger, 1974; Kako, 1978; Furtan, 1981; Lopez, 1984; Abedin, 1985; Kuroda 1987) have been done by various researchers related to the present study. But most of these are related to foreign environments. Therefore, there is a need to undertake such a study for reasons such as (i) updating estimate of technical change and elasticity estimates in a changed condintion.

Objectives of the Study :

The specific objectives of the study are as follows :

i) To estimate the elasticity of demand for the factors of production.

ii) To estimate the bias in technical change for rice production over the years.

The paper is organized in four sections. Following this introduction, nature of data, data collection procedure, conceptual framework for the cost function and technical change have been elaborated in section II. Analysis of the findings has been made in section III while the summary, conclusions and policy implications have been focussed in the last section.

II. METHODOLOGY

Nature, Sources and Collection of Data

Secondary data were used to carry out the study. The data required for estimating the cost function are the total cost of inputs, the quantity of rice and the prices and cost shares of six factors of production such as human labor, bullock labor, fertilizer, irrigation, seeds and other inputs. The data related to cost were collected from the various issues of Agro-Economic Research conducted by the Ministry of Agriculture from 1978-79 to 1992 (BBS 1980, 1987 and 1992). The data from 1972-73 to 1977-78 were collected from BRRI annual reports (1972-73 to 1977-78). Both the Ministry of Agriculture and BRRI used survey method to collect the data. The data from two different sources were found consistent.

The Translog Cost Function

The Cobb-Douglas production function to one output and more than two factors of production implies that Allen's partial elasticities of substitution for all pairs of two factors of production are unity. The application of the CES function to the one output and more than two inputs case implies that all of the Allen's partial elasticities of substitutions (APES) are independent of factor prices and are identical for all pairs of two factors of production as Uzawa (1962) has shown. This approach precludes the complementary relationship between pairs of two factor inputs. The substitutability and complementarity relationships among factor inputs are the objects to be investigated rather than assumed to be constant in the research of agricultural growth.

Considering the severe limitations of the above production function Christensen, Jorgenson and Lau (1971) have developed the transcendental logarithmic function. This function does not imply any restriction in the APES between pairs of factor inputs. Using the translog function it is possible to investigate the substitutory and complementary relationships between pairs of factor inputs. This property of translog function can be considered a great advantage over the discussed production function. The information on substitutability and complementarity between pairs of factor inputs will help understand the process of agricultural growth. So the translog function appears to have great potential as a truly useful analytical model. Therefore, in this study the factor demand analysis of rice sector of Bangladesh has been analyzed through the estimation of multifactor translog cost function.

The present study assumes that the farmers production technology is represented by the following translog cost function.

$$C = fn(Q, P_h, P_b, P_s\, P_f, P_i, P_o, t) \tag{1.1}$$

where, C = total cost, Q = Output, P_h = Price of human labor, P_b = Price of bullock labor, P_s = Price of seeds, P_f = Price of fertilizer, P_i = Price of irrigation, P_o = Price of other inputs, t = annual index.

The translog cost function is specified as below:

$$LnC = \alpha_O + \alpha_Q 1nQ + \Sigma\alpha_i 1nP_i + \in_t 1nt + 1/2\beta_{QQ}(1nQ)^2 + 1/2\ \Sigma\beta_{ii}(1nP_i)^2 + \Sigma\Sigma\beta_{ij}1nP_iP_j + \Sigma\delta Q_i 1nQ1nP_i + \varnothing_{tQ}1nt1nQ + \Sigma\mu_{ti}1nt1nP_i + 1/2\in_{tt}(1nt)^2 \tag{1.2}$$

The translog cost function has some constraints (Binswanger, H. P. 1974) on its parameters :

(i) It is assumed that the translog cost equation is twice differentiable, so that the Hessian of this equation is symmetric, i.e. $\beta_{ij} = \beta_{ji}$, where, i,j, = H, B, S, F, I, O.

(ii) Since it is a cost function, it has to satisfy the economic constraints of linear homogeneity, i. e. total cost doubles when all factor prices double. This implies :

$$\Sigma\alpha_i = 1,\ \Sigma\beta_{ij} = O, \Sigma\beta_{ii} = O, \Sigma\delta_{Qi} = O, \Sigma\mu_{ti} = O \text{ where, i, j = H, B, S, F, I, O}$$

(iii) The cost function must be an increasing function of the input prices. That is :

$$\frac{\delta 1nC}{\delta 1nP_i} = \alpha_i + \Sigma\ \beta_{ij}\ 1nP_j + \Sigma\beta_{ii}1nP_i + \Sigma\ \delta_{Qi}1nQ + \Sigma\mu_{ti}1nt \tag{1.3}$$

Cost Share Equations

The cost share equation was derived through the Shepherd duality theorem (Shepherd, 1970) as

$$S_i = \frac{\delta C/\delta P_i \cdot P_i}{\delta C} = \delta 1nC/\delta 1nP_i \tag{1.4}$$

where, S_i denotes the cost share of factor i. Taking the derivative of the equation (1.4) the cost shares can be expressed as follows

$$S_i = \alpha_i + \Sigma\ \beta_{ij}\ 1nP_j + \beta_{ii}1nP_i + \delta_{Qi}1nQ + \mu_{ti}1nt \tag{1.5}$$

All of the parameters of the cost share equations appears in the translog cost function. The equality of these parameters is a necessary condition for the system of the equations to be consistent with cost minimizing behavior.

Technical Change : Hicks Approach

Hicks classification of technical change can be expressed in terms of the factor share. Technical progress is labor using, neutral or capital using according as the relative share of capital declines, remains nuchanged or increases at a given factor combination (Hicks, 1963). By inversion, all of the above relations may be expressed in terms of the relative share of labor. Symbolically,

$$\frac{\delta\left(\frac{F_iX_i}{F_jX_j}\right)}{\delta t} \Bigg| \frac{X_i}{X_j} = \frac{S_i}{S_j}\left(\frac{\beta_{ij}}{S_i} \quad \frac{\beta_{jt}}{S_j}\right) \begin{array}{l} > \text{j-saving} \\ = \text{O neutral} \\ < \text{i-saving} \end{array} \tag{1.6}$$

where, i, j = H, B, S, F, I

Factor Demand Elasticity and Elasticity of Substitution

The Allen partial elasticity of substitution (APES) and price elasticity of demand for factor inputs were calculated as follows :

$$\sigma_{ii} = \frac{\beta_{ii} + S_i^2 - S_i}{S_i^2} \quad \text{for all i,} \tag{1.7}$$

$$\sigma_{ij} = \frac{\beta_{ij} + S_iS_j}{S_iS_j} \quad \text{for all } i \neq j. \tag{1.8}$$

where i, j = H, B, S, F, I,

σ_{ij} are the Allen's partial elasticity of substitution.

$$E_{ii} = \frac{\delta \ln X_i}{\delta \ln P_i} = \frac{\beta_{ii} + S_i^2 - S_i}{S_i} = S_i\sigma_{ii} \tag{1.9}$$

$$E_{ji} = \frac{\delta \ln X_i}{\delta \ln P_j} = \frac{\beta_{ij} + S_iS_j}{S_j} = S_j\,\sigma_{ij} \tag{1.10}$$

where E_{ii} and E_{ij} are the own price elasticity and cross price elasticity respectively.

Standard error of the APES were also calculated using the following formula

$$SE(\sigma_{ij}) = \frac{SE(\beta_{ij})}{S_iS_j} \tag{1.11}$$

The standard error of each of the own price elasticity of derived demand were also calculated using the following formula

$$SE(\mu_{ii}) = \frac{SE(\beta_{ii})}{S_i} \tag{1.12}$$

where, i = H, B, S, F, I

The standard error of the cross price elasticity of derived demand were calculated using the following formula

$$SE(E_{ij}) = \frac{SE(\beta_{ij})}{S_i S_j} \qquad (1.13)$$

where i, j = H, B, S, F, I

III. ANALYSIS OF THE FINDINGS

The parameters of the translog cost function and cost share equations estimated using the SUR and OLS technique are presented in Table 1. Ordinary least square estimates provides

Table 1. SURE and OLS estimates of the parameters of the cost share equations.

Parameters	SURE estimates	OLS estimates
α_o	0.8 (226.099)*	0.394 (4.716)*
α_h	0.344 (60.153)*	0.114 (4.27)*
α_b	0.29 (71.11)*	0.25 (8.99)*
α_s	0.22 (44.15)*	0.215 (4.15)*
α_f	0.065 (15.82)*	0.19 (9.12)*
α_i	0.077 (18.43)*	0.054 (1.27)
β_{hh}	0.126 (72.88)*	0.26 (58.07)*
β_{bb}	0.116 (95.2)*	0.137 (77.34)*
β_{ss}	0.07 (40.84)*	0.10 (39.50)*
β_{ff}	0.089 (64.34)*	0.12 (75.83)*
β_{ii}	0.035 (22.66)*	0.058 (18.72)*
β_{hb}	−0.095 (−90.16)*	−0.075 (−44.53)*
β_{hs}	−0.02 (−18.47)*	−0.057 (−42.93)*
β_{hf}	−0.031 (−26.00)*	−0.057 (−29.04)*
β_{hi}	0.021 (17.44)*	−0.032 (−16.77)*
β_{bs}	0.006 (5.23)*	−0.015 (−10.62)*
β_{bf}	−0.029 (−32.26)*	−0.025 (−12.33)*
β_{bi}	−0.005 (4.64)*	−0.0077 (−3.87)*
β_{sf}	−0.015 (−16.39)*	−0.015 (−3.89)*
β_{si}	−0.028 (22.41)*	−0.0055 (−1.47)
β_{fi}	−0.027 (−30.75)*	0.0067 (−4.46)*
δ_{qh}	−0.003 (−3.67)*	−0.004 (−1.17)
δ_{qb}	−0.006 (−11.33)*	−0.0062 (−.66)***
δ_{qs}	−0.016 (−21.09)*	−0.0033 (0.484)
δ_{qf}	0.013 (25.94)*	0.0015 (0.54)
δ_{qi}	−0.003 (−5.33)*	0.13 (2.22)**
μ_{th}	0.0019 (5.4)*	0.0002 (0.43)
μ_{tb}	0.0027 (7.49)*	0.0013 (2.70)**
μ_{ts}	0.0011 (1.72)***	0.0008 (0.91)
μ_{tf}	−0.0015 (−5.13)*	−0.0005 (−1.45)
μ_{ti}	−0.0025 (−4.45) hs	−0.0017 (−2.27)**

Note : Figures in the parentheses are t-values. '*' means highly significant (at 1% level), '**' means significant at 5% level and '***' means significant at 10% level.

inefficient estimates if the errors from each share equations are contemporaneously related and with generilized least square estimates, the numerical estimates may not be invariant with respect to the equation deleted (Boyle, G 1982). Most of the parameters estimated through SURE were highly significant at 1 percent level except time trend. The cost shares were all positive indicating that the monotonicity of the cost function with respect to input prices were satisfied globally. To avoid the inefficiency of the estimates Allen's partial elasticities of substitutions (APES), own and cross price elasticities of factor demand and bias of technical change were calculated based on the SURE estimates of parameter of the translog cost function and cost share equations.

Some statistics of the SURE estimates:

Wald test:

Chi-Squared (23 Deg. freedom) = 38191.00

Significance level for test = 0.00000

Log-Likelihood = 293.1334

Log-determinatnt of $\Sigma = -38.0000$

Allen Partial Elasticities of Substitution (APES)

APES between factor i and j measures the normalized response of a change in the price of the j-th factor on the amount demanded of the i-th factor when output is held constant but when the quantities of all other factors were permitted to vary. The calculated Allen partial elasticities at mean level are presented in Table 2.

Table 2. APES at mean level over the years (1971-72 to 1992-93).

	Human labor	Bullock labor	Seeds	Fertilizer	Irrigation
Human labor	—				
Bullock labor	−0.362	—			
Seeds	0.56	1.41	—		
Fertilizer	0.446	−0.596	−0.328	—	
Irrigation	1.786	1.536	−3.94	−2.75	—

The APES at mean level show that human labor is a strong substitute for irrigation water (σ_{hi} is 1.786) than those for seeds (σ_{hs} is 0.56) and fertilizer (σ_{fh} is 0.446). Bullock labor is also a stronger substitute for seeds (σ_{bs} is 1.41) and irrigation (σ_{bi} is 1.54). It is found that seed is highly complement with irrigation water (σ_{si} is −3.94) compared to that of fertilizer and irrigation (σ_{fi} is −2.75), bullock labor and fertilizer (σ_{bf} is −0.60), human labor and bullock labor (σ_{hb} is −0.36) and seeds and fertilizer (σ_{sf} is −0.33). The substitutory relationship between fertilizer and human labor indicates that if the price of fertilizer increases then the use of human labor increases because the farmers need to use more labor for good quality tillage and intercultural operations for getting higher production with less fertilizer. Similarly, the substitutory relationship between human labor and irrigation implies that if the price of irrigation increases then the use of water decreases as well as the use of human labor increases for good quality cultivation of land.

Complementary relationship was found with seeds and fertilizer, i. e. if the price of fertilizer increases then its use decreases as well as use of seeds also decreases; because HYV seeds are highly sensitive to use of fertilizers. Complementary relationship was also found with seeds and irrigation. If the price of seeds increases then the use of seeds decreases so that the need for irrigation water become less and that is why application of water decreases. Furthermore, there was complementary relationship between fertilizer and irrigation, i.e. if the price of fertilizer increases than the use of fertilizer decreases. Because fertilizer is complementary to irrigation water, the reduction in fertilizer use leads to a decline in use of irrigation water. So fertilizer price should be kept stable for optimum use of seeds and irrigation for their complementary relationship with fertilizer. Fertilizer delivery system should be arranged by the government for ensuring a fair price of fertilizer. Higher rice production requires quality tillage, good quality and adequate seeds, application of recommended dose of fertilizer and water. So government should take care about the stable prices and supply of those inputs for higher yield as well as higher production.

Own and Cross Price Elasticity of Derived Demand

The own price elasticity and cross price elasticity are also shown by the following matrix.

Table 3. The own price elasticity and cross price elasticity of derived demand at mean level over the years (1971-72 to 1992-93).

	Human labor	Bullock labor	Seeds	Fertilizer	Irrigation
Human labor	−0.262				
Bullock labor	−0.143	−0.074			
Seeds	0.055	0.136	−0.16		
Fertilizer	0.055	−0.071	−0.037	−0.136	
Irrigation	0.106	0.093	−0.23	−0.159	−0.346

Mean level own price elasticity of derived demand for bullock labor is highly inelastic (μ_{bb} is 0.074) compared to those of fertilizer (μ_{ff} is 0.14), seeds (μ_{ss} is 0.16), human labor (μ_{hh} is 0.26) and irrigation (μ_{ii} is 0.35). Own price elasticities indicated that irrigation is relatively more price responsive than those of human labor, seeds, fertilizer and bullock labor. The cross price elasticities explains the same as APES but the magnitudes are different. The own price elasticities of derived demand have the correct sign, i.e. negative, which implies that an increase in the price of the factors of production results in a decrease in the demand for the factors of production. Own price elasticity of human labor states that 1% increase in the price of human labor declines its use by 0.24% to 0.28%, i.e. human labor is price inelastic over the years.

Own price elasticities of bullock labor were highly inelastic except 1977-78 and 1978-79. It is found that 1% increase in the price of bullock labor declines its use by 0.03% to 0.10% only (Appendix 1). Seed, fertilizer and irrigation were also price inelastic. The standard error of the own price elasticity of derived demand implies that most of the elasticities were statistically significant.

Bias in technical change

The bias in technical change has been calculated for the period 1971-72 to 1992-93 and reported in Table 4.

Technical change is neutral when marginal rate of substitution between factors i and j equals the inverse of their price ratio. Because of the substitutory relationship between human labor and seeds, if the price of human labor increases then the use of seeds increases which implies seed using technology relative to human labor. Human labor and fertilizer, human labor and irrigation are substitute with each other, as a result if the price of fertilizer and irrigation increases then the use of human labor increases which in turn known as human labor using technology relative to fertilizer and irrigation, i. e. labor intensive technology. In the same way, bullock labor and seeds, bullock labor and irrigation are substitute with each other. If the price of seeds and irrigation increases relative to bullock labor then the use of seeds and irrigation decreases, i.e. bullock labor using technology relative to seeds and irrigation. So it is clear that the rice production technology is labor intensive, i.e. both human labor and bullock labor using relative to fertilizer, seeds and irrigation. There was a complementary relationship between human labor and bullock labor, i. e. if the price of human labor increases then the use of human labor as well as use of bullock labor decreases but the price of bullock labor was relatively higher so that factor share of bullock labor was higher than the human labor. Complementary relationship was also observed in the case of bullock labor and fertilizer, seed and fertilizer, seed and irrigation, and fertilizer and irrigation. In all the cases factor share of bullock labor was increasing than fertilizer, factor share of seed was increasing than fertilizer and irrigation, factor share of fertilizer was increasing than irrigation. Capital intensive technology in agriculture is essential to boost up its production status. So with a view to turning into capital intensive from labor intensive technology the price of seeds, fertilizer and irrigation should kept at least stable and if possible subsidy on those inputs or credit facility should be provided to the farmers.

Table 4. Estimates of the bias of technical change over the years for different inputs of rice production.

YEAR	TEHB	TEHS	TEHF	TEHI	TEBS	TEBF	TEBI	TESF	TESI	TEFI
1971-72	−0.04	−0.025	0.062	0.30	0.01	0.038	0.13	0.02	0.082	0.049
1972-73	−0.04	−0.029	0.049	0.57	0.01	0.032	0.24	0.016	0.14	0.13
1973-74	−0.039	−0.027	0.039	0.94	0.01	0.027	0.39	0.013	0.24	0.28
1974-75	−0.039	−0.025	0.046	0.54	0.01	0.03	0.23	0.015	0.14	0.13
1975-76	−0.038	−0.021	0.05	0.27	0.017	0.038	0.28	0.01	0.15	0.16
1976-77	−0.042	−0.026	0.057	0.75	0.011	0.035	0.30	0.019	0.195	0.16
1977-78	−0.015	−0.019	0.073	0.56	0.055	0.005	0.33	0.026	0.167	0.10
1978-79	−0.02	−0.025	0.07	0.43	0.006	0.049	0.24	0.023	0.12	0.074
1979-80	−0.047	−0.031	0.061	0.49	0.011	0.36	0.19	0.019	0.12	0.09
1980-81	−0.047	−0.033	0.068	0.29	0.011	0.039	0.12	0.02	0.072	0.04
1981-82	−0.044	−0.036	0.065	0.25	0.01	0.038	0.11	0.019	0.061	0.037
1982-83	−0.04	−0.034	0.066	0.25	0.01	0.039	0.11	0.020	0.062	0.036
1983-84	−0.064	−0.033	0.062	0.35	0.013	0.034	0.13	0.019	0.085	0.058
1984-85	−0.05	−0.033	0.061	0.36	0.011	0.035	0.14	0.019	0.088	0.061
1985-86	−0.049	−0.039	0.069	0.26	0.011	0.039	0.11	0.020	0.062	0.037
1986-87	−0.055	−0.05	0.071	0.25	0.011	0.038	0.10	0.019	0.055	0.033
1987-88	−0.052	−0.053	0.06	0.28	0.01	0.034	0.11	0.016	0.06	0.045
1988-89	−0.05	−0.05	0.068	0.26	0.01	0.038	0.11	0.019	0.058	0.037
1989-90	−0.052	−0.053	0.08	0.23	0.01	0.043	0.09	0.021	0.05	0.026
1990-91	−0.052	−0.063	0.088	0.21	0.01	0.046	0.09	0.022	0.043	0.020
1991-92	−0.054	−0.065	0.081	0.22	0.009	0.043	0.09	0.02	0.044	0.024
1992-93	−0.055	−0.067	0.079	0.22	0.01	0.042	0.09	0.02	0.044	0.024

IV. SUMMARY AND CONCLUSION

Allen partial elasticities of substitution for the years 1971-72 to 1992-93 indicated that there was a complementary relationship between the human labor and bullock labor, bullock labor and fertilizer, seeds and fertilizer, seeds and irrigation, fertilizer and irrigation. On the other hand, substitutory relationships between human labor and irrigation, human labor and seeds, human labor and fertilizer, bullock labor and seeds, bullock labor and irrigation were obtained. The own price elasticities of derived demand of every factors of rice production had the expected sign i. e. negative, and inelastic which implies that an increase in the price of a factor of production decreases the demand for that factor at a lower rate and vice versa. The time series estimates of the elasticities indicated that usages of inputs did not decline so much against price increase. This implies that farmers kept using the inputs even the prices went up. The reduction in input use was observed in the case of irrigation. The technical change in rice production of Bangladesh was found to be human labor saving relative to bullock labor and seed, fertilizer saving relative to human labor, bullock labor and seed, irrigation saving relative to human labor, bullock labor, seed and fertilizer i.e. human labor using relative to fertilizer and irrigation. Rice production technology of Bangladesh according to the study reveals that the farmers of Bangladesh follow bullock labor using technology relative to human labor, seed, fertilizer and irrigation. The reported results also showed that the rice producers of Bangladesh are seed users relative to human labor, fertilizer and irrigation. The technical change also occurred as fertilizer using relative to irrigation. In general, the rice production technology of Bangladesh is both labor intensive and capital intensive. This situation may be treated as transition to the modernization of agriculture.

Policy Implications

i) Human labor, bullock labor, seeds, fertilizer and irrigation are price inelastic and negative but irrigation is less price inelastic than the others. So an increase in the price of a factor of production decreases the demand for that factor at a lower rate and vice versa.

ii) Farmers can substitute human labor for fertilizer, human labor for irrigation, human labor for seeds, bullock labor for seeds, bullock labor for irrigation. Farmers can substitute human labor for fertilizer with a view to maintaining the yield level by increasing weeding and intercultural operation. Bullock labor can be increased for land preparation so that seed germination rate increases and hence lower seed rate is required. For irrigated crop culture farmers who are facing the bullock power shortage can increase the number of irrigation with less use of bullock power.

iii) Complementary relationship was found in the case of human labor with bullock labor, bullock labor with fertilizer, seeds with fertilizer, seeds with irrigation and fertilizer with irrigation. Increasing the price of fertilizer declines the use of it and in the second stage declines the use of irrigation because of their complementary relationship which affects the HYV adoption. The same kind of effect may be observed if the price of seeds and irrigation increases because of their complementary relationship. So the policy implications is that the price of seeds, fertilizer and irrigation should be kept low for the increasing use of those inputs and thus the adoption of HYV rice will be accelerated.

iv) The rice production technology of Bangladesh is to some extent labor intensive (i.e. human labor using relative to fertilizer and irrigation, bullock labor using relative to human labor, seed, fertilizer and irrigation) and to some extent capital intensive (i.e. seed using relative to human labor, fertilizer and irrigation). This situation may be treated as transition to the modernization of agriculture.

v) This transition process can be accelerated through strengthening the agricultural credit program and improving inputs distribution system. Capital intensive technology in agriculture is essential to boost up its production status. So with a view to turning into capital intensive from labor intensive technology the price of seeds, fertilizer and irrigation should kept at least stable and if possible subsidy on those inputs or credit facility should be provided to the farmers.

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Appendix 1. The own price elasticity of derived demand of factors of rice production over the years (1971-72 to 1992-93).

Year	µhh	µbb	µss	µff	µii
1971-72	−0.267	−0.089	−0.243	−0.1.42	−0.403
	(0.0038)	(0.0079)	(0.016)	(0.011)	(0.024)
1972-73	−0.273	−0.0825	−0.198	−0.212	−0.0203
	(0.0039)	(0.0081)	(0.017)	(0.010)	(0.33)
1973-74	-0.277	-0.076	-0.202	-0.272	-0.026
	(0.0040)	(0.0081)	(0.017)	(0.009)	(0.044)
1974-75	−0.272	−0.086	−0.228	−0.234	−0.221
	(0.0039)	(0.008)	(0.016)	(0.0097)	(0.032)
1975-76	−0.72	−0.094	−0.26	−0.209	−0.141
	(0.0039)	(0.0079)	(0.015)	(0.010)	(0.036)
1976-77	−0.269	−0.074	−0.23	−0.169	−0.097
	(0.0038)	(0.0082)	(0.016)	(0.011)	(0.038)
1977-78	−0.284	−0.24	−0.251	−0.044	−0.177
	(0.0043)	(0.0057)	(0.016)	(0.013)	(0.034)
1978-79	−0.279	−0.21	−0.216	−0.075	−0.28
	(0.0041)	(0.0063)	(0.017)	0.013)	(0.030)
1979-80	−0.264	−0.55	−0.202	−0.151	−0.269
	(0.0037)	(0.0084)	(0.017)	(0.011)	(0.030)
1980-81	−0.258	−0.0628	−0.193	−0.122	−0.421
	(0.0036)	(0.0083)	(0.017)	(0.012)	(0.023)
1981-82	−0.259	−0.0812	−0.169	−0.138	−0.451
	(0.0036)	(0.0081)	(0.018)	(0.012)	(0.021)
1982-83	−0.26	−0.099	−0.181	−0.129	−0.452
	(0.0036)	(0.0078)	(0.018)	(0.012)	(0.021)
1983-84	−0.253	0.0257	−0.204	−0.161	−0.379
	(0.0035)	(0.0094)	(0.017)	(0.011)	(0.025)
1984-85	−0.258	−0.0438	−0.196	−0.158	−0.366
	(0.0036)	(0.0086)	(0.017)	(0.011)	(0.025)
1985-86	−0.255	−0.056	−0.16	−0.123	−0.446
	(0.0036)	(0.0084)	(0.018)	(0.012)	(0.021)
1986-87	−0.251	−0.024	−0.099	−0.116	−0.458
	(0.0035)	(0.0088)	(0.02)	(0.012)	(0.021)
1987-88	−0.256	−0.0338	−0.07	−0.169	−0.431
	(0.0036)	(0.0087)	(0.021)	(0.011)	(0.022)
1988-89	−0.255	−0.0504	−0.091	−0.124	−0.446
	(0.0036)	(0.0085)	(0.02)	(0.012)	(0.021)
1989-90	−0.251	−0.0436	−0.077	−0.068	−0.477
	(0.0035)	(0.0086)	(0.021)	(0.013)	(0.02)
1990-91	−0.249	−0.0486	−0.024	−0.031	−0.496
	(0.0035)	(0.0085)	(0.022)	(0.013)	(0.019)
1991-92	−0.249	−0.034	−0.017	−0.067	−0.489
	(0.0035)	(0.0087)	(0.022)	(0.013)	(0.019)
1992-93	−0.249	−0.029	−0.0055	−0.076	−0.488
	(0.0035)	(0.0087)	(0.023)	(0.013)	(0.019)

Note : Figures in the parentheses indicate standard errors of the respective estimates.

Appendix 2. Allen's Partial Elasticities of Substitution of factors of rice production over the years (1971-72 to 1992-93).

Year	δhb	δhs	δhf	δhi	δbs	δbf	δbi	δsf	δsi	δfi
1971-72	−0.358	0.607	0.44	1.71	1.35	−0.549	1.474	−0.133	−2.94	−2.39
	(0.015)	(0.021)	(0.021)	(0.04)	(0.067)	(0.048)	(0.10)	(0.069)	(0.17)	(0.11)
1972-73	−0.42	0.559	0.488	2.03	1.38	−0.383	1.675	−0.083	−5.00	−3.22
	(0.016)	(0.024)	(0.019)	(0.058)	(0.073)	(0.038)	(0.15)	(0.066)	(0.27)	(0.14)
1973-74	−0.478	0.549	0.536	2.40	1.38	−0.228	1.90	0.053	−6.89	−3.90
	(0.016)	(0.024)	(0.018)	(0.079)	(0.073)	(0.041)	(0.2)	(0.058)	(0.35)	(0.16)
1974-75	−0.06	0.584	0.513	2.00	1.36	−0.314	1.654	0.017	−4.56	−2.93
	(0.016)	(0.023)	(0.019)	(0.056)	(0.069)	(0.042)	(0.14)	(0.06)	(0.25)	(0.13)
1975-76	−0.387	0.608	0.488	2.12	1.33	−0.365	1.721	0.025	−4.85	−3.63
	(0.015)	(0.021)	(0.019)	(0.063)	(0.064)	(0.047)	(0.16)	(0.06)	(0.26)	(0.15)
1976-77	−0.413	0.591	0.457	2.16	1.37	−0.517	1.787	−0.11	−5.54	−4.25
	(0.016)	(0.022)	(0.021)	(0.066)	(0.07)	(0.04)	(0.17)	(0.068)	(0.29)	(0.17)
1977-78	−0.11	0.559	0.265	2.17	1.25	−0.287	1.499	−0.29	−4.68	−4.73
	(0.012)	(0.024)	(0.028)	(0.066)	(0.047)	(0.042)	(0.11)	(0.079)	(0.25)	(0.19)
1978-79	−0.152	0.554	0.33	1.96	1.29	−0.344	1.467	−0.316	−4.19	−3.71
	(0.013)	(0.024)	(0.025)	(0.054)	(0.055)	(0.05)	(0.10)	(0.08)	(0.23)	(0.15)
1979-80	−0.411	0.584	0.457	1.89	1.40	−0.609	1.639	−0.199	−4.41	−3.26
	(0.016)	(0.022)	(0.021)	(0.05)	(0.076)	(0.052)	(0.14)	(0.073)	(0.24)	(0.14)
1980-81	−0.356	0.589	0.447	1.65	1.40	−0.666	1.475	−0.276	−3.13	−2.36
	(0.015)	(0.022)	(0.021)	(0.037)	(0.076)	(0.049)	(0.10)	(0.078)	(0.18)	(0.11)
1981-82	−0.325	0.57	0.458	1.61	1.40	−0.577	1.43	−0.294	−3.004	−2.05
	(0.015)	(0.023)	(0.021)	(0.034)	(0.077)	(0.048)	(0.09)	(0.079)	(0.18)	(0.10)
1982-83	−0.292	0.577	0.448	1.61	1.38	−0.554	1.416	−0.287	−2.91	−2.08
	(0.014)	(0.023)	(0.021)	(0.034)	(0.073)	(0.055)	(0.09)	(0.079)	(0.17)	(0.10)
1983-84	−0.503	0.605	0.493	1.69	1.44	−0.773	1.589	−0.176	−3.44	−2.45
	(0.017)	(0.021)	(0.019)	(0.039)	(0.085)	(0.05)	(0.13)	(0.072)	(0.20)	(0.11)
1984-85	−0.40	0.59	0.477	1.73	1.41	−0.618	1.548	−0.197	−3.61	-2.55
	(0.016)	(0.022)	(0.02)	(0.041)	(0.078)	(0.052)	(0.12)	(0.073)	(0.20)	(0.12)
1985-86	−0.353	0.57	0.454	1.61	1.42	−0.682	1.453	−0.344	−3.11	-2.16
	(0.15)	(0.023)	(0.021)	(0.034)	(0.081)	(0.055)	(0.099)	(0.082)	(0.18)	(0.10)
1986-87	−0.396	0.54	0.458	1.58	1.48	−0.781	1.46	−0.484	−3.36	-2.10
	(0.015)	(0.025)	(0.21)	(0.033)	(0.093)	(0.05)	(0.10)	(0.091)	(0.19)	(0.10)
1987-88	−0.408	0.511	0.491	1.63	1.50	−0.612	1.489	−0.416	−3.84	-2.04
	(0.016)	(0.026)	(0.019)	(0.036)	(0.095)	(0.053)	(0.11)	(0.087)	(0.21)	(0.099)
1988-89	−0.366	0.527	0.455	1.61	1.47	−0.692	1.457	−0.48	−3.53	-2.16
	(0.015)	(0.026)	(0.021)	(0.034)	(0.09)	(0.058)	(0.099)	(0.09)	(0.20)	(0.10)
1989-90	−0.353	0.527	0.42	1.55	1.48	−0.857	1.426	−0.639	−3.27	-2.17
	(0.015)	(0.026)	(0.022)	(0.031)	(0.093)	(0.06)	(0.092)	(0.10)	(0.19)	(0.10)
1990-91	−0.335	0.497	0.394	1.52	1.51	−0.938	1.40	−0.844	−3.33	-2.16
	(0.015)	(0.027)	(0.023)	(0.029)	(0.099)	(0.059)	(0.087)	(0.11)	(0.19)	(0.10)
1991-92	−0.364	0.493	0.422	1.53	1.53	−0.887	1.417	−0.773	−3.45	-2.07
	(0.015)	(0.027)	(0.022)	(0.03)	(0.10)	(0.058)	(0.091)	(0.11)	(0.20)	(0.10)
1992-93	−0.374	0.486	0.43	1.53	1.54	−0.878	1.423	−0.775	−3.54	-2.04
	(0.015)	(0.028)	(0.022)	(0.03)	(0.10)	(0.058)	(0.092)	(0.11)	(0.20)	(0.099)

Note : Figures in the parentheses indicate the standard errors of the respective estimates.

Appendix 3. The cross price elasticities of derived demand of different factors of rice production over the years (1971-72 to 1992-93).

Year	μhb	μhs	μhf	μhi	μbs	μbf	μbi	μsf	μsi	μfi
1971-72	–0.14	0.067	0.053	0.11	0.148	–0.066	0.0955	–0.016	–0.19	–0.155
1972-73	–0.17	0.057	0.067	0.093	0.14	–0.052	0.077	–0.011	–0.23	–0.148
1973-74	–0.19	0.056	0.083	0.084	0.141	–0.035	0.066	0.0082	–0.24	–0.136
1974-75	–0.17	0.062	0.073	0.094	0.145	–0.045	0.078	0.0024	–0.215	–0.138
1975-76	–0.17	0.069	0.066	0.089	0.151	–0.05	0.073	0.0034	–0.205	–0.153
1976-77	–0.17	0.063	0.058	0.086	0.146	–0.065	0.071	–0.014	–0.22	–0.17
1977-78	–0.19	0.063	0.028	0.096	0.139	–0.03	0.066	–0.03	–0.207	–0.209
1978-79	–0.17	0.058	0.036	0.10	0.135	–0.038	0.076	–0.034	–0.216	–0.19
1979-80	–0.15	0.06	0.056	0.096	0.142	–0.075	0.083	–0.024	–0.224	–0.165
1980-81	–0.13	0.059	0.052	0.11	0.14	–0.078	0.099	–0.032	–0.211	–0.159
1981-82	–0.13	0.055	0.055	0.12	0.135	–0.069	0.103	–0.035	–0.217	–0.148
1982-83	–0.13	0.057	0.053	0.12	0.136	–0.066	0.103	–0.034	-0.212	–0.151
1983-84	–0.13	0.062	0.061	0.10	0.148	-0.096	0.098	–0.022	–0.212	-0.151
1984-85	–0.14	0.06	0.059	0.10	0.142	–0.077	0.093	–0.024	–0.217	–0.154
1985-86	–0.13	0.055	0.053	0.11	0.136	–0.08	0.104	–0.04	–0.22	–0.155
1986-87	–0.12	0.047	0.053	0.12	0.129	–0.091	0.108	–0.056	–0.247	–0.155
1987-88	–0.13	0.043	0.062	0.11	0.126	–0.077	0.102	–0.0525	–0.265	–0.141
1988-89	–0.13	0.046	0.053	0.11	0.127	–0.081	0.104	–0.056	–0.253	–0.154
1989-90	–0.12	0.045	0.045	0.12	0.126	–0.093	0.11	–0.069	–0.253	–0.168
1990-91	–0.11	0.039	0.04	0.12	0.12	–0.096	0.114	–0.087	–0.272	–0.176
1991-92	–0.11	0.039	0.046	0.12	0.12	–0.096	0.114	–0.083	–0.277	–0.166
1992-93	–0.11	0.037	0.047	0.12	0.119	–0.096	0.113	–0.085	–0.282	–0.163