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Change in Input Relations in Bangladesh Agriculture, 1973-1995

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The major forces of technological change and input substitution induced by relative factor price changes have led to important changes in the input mix in Bangladesh agriculture. The labour input has been replaced by fertiliser and irrigation. This change in input use raises significant issues with respect to the nature of factor substitution and input demand. This study sheds light on these issues by using the translog cost function approach. The findings reveal that the AES between land and fertiliser (N-F) shows increasing substitutability relationship over time, whereas the AES between fertiliser and irrigation (F-I) displays high substitutability throughout the study period along with a declining trend in the latter period.

Keywords: Bangladesh Agriculture, Input Relationships
JEL Classification: D00, Q10, Q12, C13, C32

I. INTRODUCTION

Changing input use is a continuous process in agriculture. Farmers change input mix due to changes in relative input prices and production technology. There has been a major re-allocation of resources in Bangladesh agriculture in the last few decades and the application of fertiliser and irrigation has become a major characteristic of modern farming. In the case of Bangladesh agriculture, land and labour should be included as inputs. But for material inputs, irrigation should be included along with fertiliser.

Inclusion of energy as a separate input is not warranted because in Bangladesh there has not been any significant use of energy in the cultivation process. Energy use has been mostly done for irrigation, which has been included as an input. Thus four inputs–land, labour, fertiliser and irrigation–have been used in this study to analyse factor substitution.

In a time series study, it is very crucial to have a proper classification of inputs, especially for a less developed country like Bangladesh. Input

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classifications used in other studies are presented in Table I. From Table I, it is observed that Binswanger (1973), Lopez (1980), Islam (1982), Chalfant (1984), Thirtle (1985), Kuroda (1987) and Ali (1991) used land as an input. It is also observed that everyone included labour as an input. In the case of fertiliser, it can be seen that Binswanger (1973), Chotigeat (1978), Islam (1982), Boyle (1982), Thirtle (1985) and Ali (1991), all have used fertiliser as a separate input. Thus, nearly all studies used land and labour as inputs. Coming to the intermediate inputs, we find the inclusion of fertiliser and energy in some studies.

Flexible forms provide more adequate tools for analysing multi-input relationships in that they allow for both substitutability and complementarity between inputs. The translog cost function, a function which belongs to the family of flexible forms and does not a priory restrict the value of elasticity of substitution, is used in the analysis of factor substitution. Early input classifications in production studies were mostly restricted to only two inputs as it is found in the Cobb-Douglas and the CES functions. But after the introduction of flexible forms, inclusion of any number of inputs became possible and consequently, other inputs, such as material and intermediate inputs, began to be considered in production function studies. In this study, the input classification is designed to study both durable and non-durable inputs.

TABLE I

INPUT CLASSIFICATION USED IN SELECTED FLEXIBLE FORM STUDIES OF THE AGRICULTURE SECTOR

Author	Year	Country	Inputs
Binswanger	1973	USA	Land Labour Fertiliser Machinery Other inputs
Brown	1978	USA	Capital Labour Materials
Chotigeat	1978	Thailand	Capital Labour Fertiliser
Lopez	1980	Canada	Land Labour Capital Intermediate inputs

(Contd. Table I)

Author	Year	Country	Inputs
Islam	1982	Canada	Land Labour Machinery Fertiliser Energy
Boyle	1982	Ireland	Fertiliser capital services Labour services Other intermediate inputs
Chalfant	1984	USA	Capital Intermediate inputs Labour Land
Thirtle	1985	USA	Land Labour Fertiliser Machinery
Akridge and Hertel	1986	USA	Labour Energy Other variable inputs Fixed inputs
Kuroda	1987	Japan	Land Labour Machinery Intermediate inputs Other inputs
Ali	1991	UK	Land Labour Machinery Fertiliser Energy

1.1 Changing Input Use in Bangladesh Agriculture

Since independence, a significant change in the use of major agricultural inputs was observed due to adoption of modern technology like fertiliser and irrigation in the Bangladesh agriculture sector. Land is the main source of all agricultural activities. As an agrarian economic base, land occupies a dominant position in the Bangladesh agricultural sector. Since independence, like other inputs, the use of land changed substantially over time. In 1972-73, total cropped area was 29039 thousand acres which increased to 33,413 thousand acres in 1994-95 (BBS, Statistical Yearbook of Bangladesh, various issues). As a core factor of production, total cropped area increased moderately. In the past, the crop sector generated most of the employment opportunities in the agriculture sector. Over time, importance of labour in the crop sector has been gradually decreasing. As smaller farms need fewer hired workers, the continuing fragmentation of land holdings and resultant proliferation of smaller farms have tended to decrease the overall demand for agriculture labour. In 1974, 77.2 per cent of labour force engaged themselves in the traditional agriculture while remaining 22.8 per cent were engaged in non-agricultural activities. But in 1991, the occupational dependence in agriculture sector declined where 54.6 per cent labour force engaged in agriculture sector and 45.4 per cent were engaged in non-agricultural sectors. This happened due to transfer of labour force from the traditional agriculture sector to the non-agriculture sector (BBS 1994).

Consumption of chemical fertilisers increased markedly. Of the various types of chemical fertilisers used in Bangladesh, urea is the most important, followed by triple super phosphate (TSP) and muriate of potash (MP). In 1972-73, urea consumption was only 277 thousand metric tons while it rapidly increased to about 1746 thousand metric tons in 1994-95 (BBS, Statistical Yearbook of Bangladesh, various issues). The remarkable increase in consumption of fertilisers happened due to large domestic production, increased farm consumption and expanded marketing role. Besides these, government policies also played a major role in creating these developments. As the most modernised component, the use of irrigation also increased during this period. Among the modern technology motorized low lift pumps (LLPs), shallow tubewells (STWs) and deep tubewells (DTWs) are dominant. Initially, public sector LLPs and DTWs covered most of the irrigated area and gradually STWs in the private sector liberally expanded. Over the years, import bar on diesel engines has been removed and there has been rapid expansion in private sector sales of STWs and DTWs. In the case of STWs, only 4 thousand acres were irrigated in 1972-73 but it rapidly increased to 3,812 thousand acres in 1994-95 (BBS, Statistical Yearbook of Bangladesh, various issues).

1.2 Objectives of the study

The specific objectives of this study are as follows: (1) to assess the input relationship by considering the signs and magnitudes of translog estimates of Allen partial elasticity of substitution (AES); (2) to analyse the changing input demand by estimating cross elasticities of input demand (ED); and (3) to explore the factors that are responsible for the changing input relationships.

II. LITERATURE REVIEW

Several researchers have conducted their researches on different aspects of agricultural inputs in Bangladesh agriculture. Khan et al. (1980) estimated a demand function for fertiliser using aggregate time series data on fertiliser sales as the dependent variable for 1968-78. The estimated price elasticity was 0.17.They argued that subsidy on fertiliser did not contribute much to the growth of fertiliser use. Khan *et al.* (1980) argued to reduce subsidy on fertiliser in Bangladesh agriculture sector. Jabber and Islam (1981) tried to verify the validity of this argument. In this paper, results of a cross section study verifying the importance of price as determinant of fertiliser demand are presented. Data collected for one year in 1980 from a sample of 100 farms in Dariapur, a village in Rangpur district. The results showed that the estimated elasticities are higher for TSP and MP compared to Urea in all crops and most of the elasticities are usually high. The elasticity for Urea was low because the current rate of application of Urea is much higher than that of TSP and MP. The results also indicated that any increase in subsidy is likely to be productive for the farmers, hence for the society as well. Shahabuddin (1985) employed Cobb-Dauglas functional form in estimating production function in traditional agriculture of Bangladesh. He analysed resource use efficiency in peasant farming; cross section farm level data have been extensively used in estimating the technical coefficients of production. In this paper, the validity of the restrictions imposed by Cobb-Dauglas functional form was tested and the test results showed that the Cobb-Dauglas restrictions were validated against both transcendental and translog functions for aman rice, pulses wheat, oilseeds and IRRI rice but not in the case of aus rice and jute and this, therefore, raises some doubts as to its indiscriminate use in estimating disaggregated production functions in peasant agriculture. Islam, Hossain and Habib (1988) found divergent extent of factor substitution in Eastern and Western region of Bangladesh. CES production function is used to measure the substitution between capital and labour for Bangladesh agriculture as a whole and for the four districts of Chittagong, Dhaka, Khulna and Rajshahi. The study showed elasticity of substitution (ES) for Chittagong and Dhaka are considerably greater than one which rejects the Cobb-Dauglas specification of unit elasticity of substitution. The extent of capital labour substitution has been greater for the Dhaka and Chittagong than Rajshahi and Khulna. This study also found that the share of labour has fallen in Dhaka and Chittagong which indicates growing mechanisation, whereas it has remained nearly constant in Khulna and Rajshahi.

Therefore, it is seen that in all the studies, there was no detail about the trends of changing input use due to changes in related input prices and production technology. So it requires a study on the changing input relationships on the basis of time series data.

III. METHODOLOGY

The translog function introduced by Christensen, Jorgenson and Lau (1973) is used in this study. Like other Flexible forms, the translog function does not impose any a priori restriction on the values of elasticity of substitution.

In the usual form, the translog cost function can be written as:

$$\ln C = a_0 + a_Y \ln Y + \frac{1}{2}\gamma_{YY}(\ln Y)^2 + \sum_i a_i \ln P_i + \frac{1}{2}\sum_i \sum_j \gamma_{ij} \ln P_i \ln P_j + \sum b_{Yi} \ln Y \ln P_i \quad (1)$$

where C = total cost

Y = aggregate output

P = prices of inputs.

The possibilities of augmented technical change have not been included in equation (1). Incorporating the technical change by including time (t), equation (1) can be modified as:

$$\ln C = a_0 + a_Y \ln Y + \frac{1}{2}\gamma_{YY}(\ln Y)^2 + \sum_i a_i \ln P_i + \frac{1}{2}\sum_i \sum_j \gamma_{ij} \ln P_i \ln P_j + \sum b_{Yi} \ln Y \ln P_i + \varphi_t t + \frac{1}{2}\varphi_{tt} t^2 + \varphi_t Y^t 1n\, Y + \sum_i \varphi_t P_i\ t \ln P_i \quad (2)$$

Equation (2) considers technical change at a constant rate and it can indicate existence and direction of technical change.

3.1 The Cost-Share Equations

According to Shephard (1953), the share of an input in total cost can be viewed as its share in the total product. This is called Shephard's Lemma. Following the Shephard's Lemma, the cost-minimising share equations for the various inputs can be obtained by logarithmically differentiating equation (2) with respect to input prices. Now the derived demand equations and the cost-share equations can be presented as:

$$\frac{\delta \ln C}{\delta \ln P_i} = S_i = a_i + \sum_{j}^{n} \gamma_{ij} \ln P_j + b_{Yi} \ln Y + \varphi_t P_i t \quad (3)$$

where Si = Share of the i-th input in total cost.

In this study, the cost-share equations are estimated with the following restrictions imposed:

(1) Adding up criteria implying that sum of the cost-shares must equal unity. Symbolically,

$$\sum_i a_i = 1$$

$$\sum_i \gamma_{ij} = 0$$

$$\sum_i b_{Yi} = 0$$

$$\sum_i \varphi_t P_i = 0 \quad (4)$$

(2) Zero degree homogeneity in prices implying that proportional changes in all input prices leave the factor shares unaltered. Symbolically,

$$\sum_j \gamma_{ij} = 0 \quad (5)$$

(3) Symmetry implying that typical properties of neoclassical production theory are satisfied:

$$\gamma_{ij} = \gamma_{ji} \quad (6)$$

Considering the above-stated restrictions which are placed on equation (3), different production structures can be reflected. In this study, both the homothetic and the non-homothetic structure of this model are empirically estimated and technical change has not been incorporated here.

3.2 Elasticities of Substitution and Demand

In the cost shares equations, the estimated gamma coefficients do not have any clear economic meaning, but these form the basis for deriving the estimate of elasticities of substitution and demand. Uzawa (1962) has demonstrated that the AES between two inputs i and j can be expressed as:

$$\sigma_{ij} = \frac{C_i C_{ij}}{C_i C_j} \tag{7}$$

where $C_i = \delta C / \delta P_i$
and $C_{ij} = \delta^2 C / \left(\delta P_i \delta P_j\right)$

where σ_{ij} denotes AES between inputs i and j. It is seen from the definition that the elasticities of substitution between any two inputs are symmetric. Equation (7) has been given in general terms. Now for the translog cost function, the AES is given by

$$\sigma_{ij} = \frac{\gamma_{ij} + S_i S_j}{S_i S_j} \tag{8}$$

The own price elasticity is given by the following equation

$$\sigma_{ii} = \frac{\gamma_{ii} + S_i^2 - S_i}{S_i^2} \tag{9}$$

where Si and Sj are the shares of the i-th and j-th input. Allen (1938) states the relationship of elasticity of substitution and elasticity of input demand thus

$$ED_{ij} = S_j \sigma_{ij} \qquad i \neq j \tag{10}$$

$$ED_{ii} = S_i \sigma_{ii} \tag{11}$$

EDs denote the elasticities of input demand where it is assumed that the cross price elasticities are not equal, that is, the share of i-th input may not be equal to the share of the j-th input.

In this study, the Full Information Maximum Likelihood (FIML) method has been applied to estimate the cost share equations. In estimating the set of equations (3), it is necessary to have a stochastic framework, thus a disturbance term, which is assumed to be normally distributed, is added to each of the equations in (3). As the sum of cost shares equal to one, it is necessary to delete one share equation to avoid over identification. But the estimates obtained are not invariant to the equation deleted. To overcome this problem, an iterative method is used to generate estimates which are invariant to the share equation deleted. The share equations are estimated using the econometric package SHAZAM.

3.3 The Data

For estimating the parameters of the translog model, most of the available data are either incomplete or are not readily available. Time series data on price and quantities of output and inputs for Bangladesh agriculture sector are used for the period 1972-73 to 1994-95. Bangladesh agriculture has witnessed radical changes during the early two decades. The trend of input prices in Bangladesh agriculture over the first two decades showed rapid changes. From 1973 until the early 1980s, the rise in input prices was relatively slow. But from the early 1980s, there were rapid increases in input prices, increasing consumption of both fertiliser and irrigation, a very moderate increase in cultivated land and decrease in the use of labour in Bangladesh agriculture became evident. The splitting of this period in this manner enables study of the impact of inflation and enables examination of whether fertiliser-irrigation substitutability and land-labour complementary relationship has changed during this period. Therefore, the first two decades of Bangladesh agriculture are studied to see whether our agriculture that moves away from the traditional mode of production to the age of modern input use and it may provide an assessment of this period.

It is necessary to separately construct the input cost shares, price indexes of four inputs and indexes of all output for estimating the coefficients of the cost share equations corresponding to the translog function.

Cost of Land

The quantity of land is defined as the total cropped area. The price of land is expressed in taka per acre and it is calculated from unweighted annual rural land price indices (BBS, Statistical Yearbook of Bangladesh, various issues). Total cropped area consists of the sum of the net-cropped area and the area sown more than once. To obtain the cost of land, the sum of opportunity cost of land and real estate taxes are included. In this study, the opportunity cost of land is assumed to be 5 per cent. In calculating the opportunity cost over the entire period, the choice of 5 per cent is considered as the fixed rate of interest. Such a rate was used by early researchers such as Binswanger (1973) and Islam (1982). It is generally assumed that any purchase of land requires some investment of money which would earn some profit if invested elsewhere. On the other hand, one needs money for rent. Thus the opportunity cost of land and real estate taxes are imputed on land. To obtain the cost of land, the sum of opportunity cost of land and real estate taxes are included. The cost of land is estimated by multiplying the price of land by quantity of land. The relevant data are obtained from various issues of the Statistical Yearbook of Bangladesh published by the Bangladesh Bureau of Statistics (BBS).

Cost of Labour

There are two measurements of labour. These are persons employed and man-hours. Though the latter is considered to be the better index of quantity of labour (Brown 1978), it is not available for Bangladesh agriculture sector. Here the quantity of labour is defined as persons employed in agriculture, forestry and fishing. These are available from the reports of various censuses and labour force surveys and are used in this study. Labour force data are available only for the discrete years in which Census and Labour Force Survey have been conducted. Hence, to construct the required annual time series data for the intervening years, data have been derived by interpolation. The Bangladesh Bureau of Statistics (BBS) reports the daily wages of agricultural labour with food and without food. This study uses the latter definition and the data are transformed into yearly wages assuming 300 working days per year. This is done to take into consideration idle days which are common in agricultural production. Thus, to obtain the cost of labour, persons employed in agriculture sector are multiplied by yearly wages. Data sources used to obtain relevant information include various issues of Statistical Yearbook of Bangladesh and Yearbook of Agricultural Statistics of Bangladesh.

Cost of Fertiliser

Fertiliser costs are defined as the sum of expenditures on fertilisers. Three types of fertiliser – Urea, Triple Super Phosphate and Muriate of Potash–which are used in the Bangladesh agricultural sector, are considered. The data on annual consumption of Urea, Triple Super Phosphate and Muriate of Potash (in thousand metric tons) are used in this study without any modifications. Considering the prices of fertiliser by type, the costs of fertiliser are derived as the per year consumption of fertilisers multiplied by the corresponding year’s prices (Taka per ton). Data on quantity and prices of fertilisers are collected from various issues of Statistical Yearbook of Bangladesh and an unofficial database on the agricultural sector in Bangladesh (Khalil 1991).

Cost of Irrigation

Irrigation cost is defined as the sum of expenses on individual irrigation methods. In Bangladesh, three types of modern irrigation methods play a dominant role. These are low lift pumps (LLPs), deep tubewells (DTWs) and shallow tubewells (STWs). Area irrigated by various methods in terms of acres is used in this study. As no systematic time series data on price of irrigation are available from official sources, some selected unofficial studies are used to obtain data on price of irrigation for some years. From these unofficial sources, per acre operating and maintenance cost is constructed. Due to non-availability of particular yearly data on prices of irrigation, the growth rates are obtained from the available data and used to approximate values for the missing years. Thus to obtain the costs of irrigation, the area irrigated by various methods are multiplied by operating and maintenance cost paid by farmers for the respective methods. Data on irrigation are obtained from various issues of the Statistical Yearbook of Bangladesh, Khalil (1991), Quasem (1987), Osmani and Quasem (1985), and Bangladesh Agriculture University (BAU 1985). Finally, total cost on irrigation is obtained as the sum of the expenditures on these inputs. Cost share of irrigation is obtained by dividing total cost by cost of irrigation.

3.4 Agricultural Output in Bangladesh

In this study, time series data on price and quantities of output are taken almost entirely from official government sources, that is, various issues of the Statistical Yearbook of Bangladesh, Yearbook of Agricultural Statistics, and Monthly Statistical Bulletins. Output classification used in this study is presented in Table II. From this table, it is seen that the data on agricultural output include cereals, cash crops, pluses, oil seeds, vegetables, fruits and spices. In the case of prices of output, the harvest price of major agricultural crops is mainly used and some data are constructed according to the requirements of the estimation procedures. In constructing the quantity index of all agricultural output, composition of 25 crops are considered to obtain the aggregate crop index.

TABLE II
OUTPUT CLASSIFICATION USED IN THIS STUDY

Agricultural Output	Crops
Cereals	Rice and Wheat
Cash Crops	Jute and Sugarcane
Pulses	*Masur*, Gram, *Mashkalai* and *Moong*
Spices	Chillies, Onion and Garlic
Oil seeds	Rape and mustard, *Til*, Linseed and Coconut
Vegetables	Brinjal,Tomato,Cauliflower and Radish
Tuber Crops	Potato
Fruits	Banana, Mango, Jackfruit and Pineapple
	and
	Tea

Agricultural output consists of both the crop and non-crop output. Non-crop agriculture means livestock, fisheries, forestry and other related activities and these subsectors made comparatively little contribution to the output growth. In Bangladesh, as crop production dominates the agriculture sector, the time series data on price and quantity of crop sector is readily available in most of the official statistics of Bangladesh.

There are two well-known indexing methods relevant for our study: the Laspeyres index and the Divisia index. For constructing the price and quantity indexes by using the yearly data, Divisia indexing method is employed in this study because this is consistent with the translog cost function. In the Laspeyres formula, it is only possible to compare the current value of the base period quantity to the base period value of the base period quantity. The Laspeyres method ignores the changes in different subcomponents and, as a result, estimated index may be biased. Laspeyres indexing procedure implicitly assume all inputs to be perfect substitutes which obviously they are not. This is especially important for the agricultural sector which is characterised by fluctuations in both production and prices. The Divisia index tries to overcome the above stated problems. Tornqvist (1936) introduced the discrete approximation to the Divisia index as a flexible weight method. In estimating the translog cost function, Berndt and Wood (1975), Griffin (1981), Norsworthy and Malmquist (1983), Aw and Roberts (1985), and Kuroda (1987) have used the Divisia indexing method in their studies. The Divisia indexing method has been chosen because it uses a flexible weighting scheme as against the widely used Laspeyres and Paasche indexes which use a fixed weighting scheme.

3.5 Cost Share Estimates and Divisia Price Indexes of Inputs

The cost shares of four inputs are presented in Table III. In analysing factor substitution, the cost shares of inputs are needed to estimate the translog cost function. From this table it is observed that the cost shares of land did not increase significantly but it fluctuated several times. In Bangladesh, a slight increase in the quantity of cultivated land was observed during the study period. Coupled with this, extreme increase in land price may have caused an increase in the cost share of land. The cost share of labour in total cost has gradually decreased during the study period. Although the daily wages of agricultural labour has increased over time, its share in total cost has declined over time. The declining tendency in labour cost share happened due to the transfer of agriculture labour force from the traditional sector to the non-agricultural sector.

TABLE III
COST SHARES OF INPUTS FOR BANGLADESH AGRICULTURE, 1973 – 1995

Year	Land	Labour	Fertiliser	Irrigation
1973	.2073	.7753	.0100	.0074
1974	.1770	.8035	.0122	.0074
1975	.1890	.7977	.0064	.0069
1976	.2231	.7590	.0103	.0076
1977	.2672	.7124	.0129	.0075
1978	.2922	.6779	.0188	.0111
1979	.3141	.6549	.0196	.0114
1980	.3149	.6546	.0178	.0126
1981	.3356	.6222	.0269	.0153
1982	.3212	.6341	.0252	.0196
1983	.3015	.6481	.0263	.0241
1984	.2905	.6561	.0301	.0233
1985	.2484	.6951	.0350	.0216
1986	.2447	.7161	.0213	.0179
1987	.2449	.7123	.0243	.0185
1988	.2597	.6917	.0276	.0211
1989	.2473	.6936	.0360	.0231
1990	.2551	.6839	.0391	.0219
1991	.2504	.6875	.0374	.0247
1992	.2408	.6963	.0374	.0254
1993	.2350	.7065	.0339	.0246
1994	.2304	.7118	.0334	.0244
1995	.2307	.7117	.0329	.0247

Though prices of fertiliser increased over time, it is considered quite moderate compared to prices of other inputs like land and labour. The remarkable increase in consumption of fertiliser and a quite moderate increase in the fertiliser prices might have caused the increasing tendency of its cost shares. The cost share of irrigation rose steadily during the study period. Area irrigated by modern method has increased and the increasing tendency of per acre operating and maintenance cost of irrigation equipment may have caused the increasing trend in the cost share of irrigation.

Divisia price indexes of input prices appear in Table IV. It is observed from this table that the highest increase occurred in the case of land, followed by the price of irrigation. The price of land increased more than eleven times and the price of irrigation increased more than nine times. Though the price of labour and fertiliser increased, these were quite moderate compared to those of land and irrigation. The Divisia quantity index of agricultural output is also constructed by combining all crops.

TABLE IV
DIVISIA PRICE INDEXES OF AGRICULTURAL INPUTS IN BANGLADESH, 1973 – 1995 (1973 = 1.000)

Year	Land	Labour	Fertiliser	Irrigation
1973	1.000	1.000	1.000	1.000
1974	1.190	1.417	1.730	1.147
1975	1.690	1.917	1.703	1.350
1976	2.050	1.864	1.727	1.580
1977	2.730	1.886	2.083	1.823
1978	3.270	2.000	2.396	2.330
1979	3.940	2.305	3.064	2.654
1980	4.540	2.640	3.721	3.049
1981	5.360	2.964	4.649	3.655
1982	5.900	3.280	5.335	4.496
1983	5.920	3.612	5.347	5.147
1984	6.480	4.147	5.868	5.817
1985	6.740	5.179	6.747	6.287
1986	7.900	6.256	6.564	7.032
1987	8.000	6.765	6.182	7.152
1988	8.100	6.098	6.229	7.935
1989	8.180	6.363	6.660	7.939
1990	8.650	6.518	6.395	8.287
1991	9.082	6.909	6.465	8.498
1992	9.536	7.430	6.500	8.830
1993	10.013	7.951	6.559	9.071
1994	10.513	8.342	6.623	9.414
1995	11.039	8.669	6.647	9.725

IV. EMPIRICAL ESTIMATES FOR BANGLADESH AGRICULTURE

Since independence, significant changes have occurred in input relations over time. It is interesting to note that, in the case of AES, most of these changes declined over time but these changes have intensified somewhat in the latter years. Based on the two structures (Homothetic and Non homothetic) of the translog model, input relationships were assessed by considering the signs and magnitudes of the translog estimates of AES and cross elasticities of input demand. It can be mentioned that under non-homothetic structure, input demand becomes a function of both input prices and the level of output whereas only input prices is considered in homothetic case. As the entire study period is considered, it enabled us to know whether fertiliser-irrigation substitution relationship declined significantly in the latter years in spite of the high irrigation cost due to high energy prices.

4.1 Estimates Based on the Homothetic Structure

Estimates of Allen partial elasticity of substitution are presented in Table V. Differences exist in sign and magnitude of AES values. Both substitutability and complementarity relationships were found to exist. Here negative values of AES imply complementarity, while the positive values indicate substitutability. The estimate for the period 1973 to 1995 showed some decline for all input pairs except the relationship of the labour-fertiliser pair.

TABLE V

ESTIMATES OF ELASTICITIES OF SUBSTITUTION FOR THE HOMOTHETIC STRUCTURE, 1973-1995

Year	N – L	N – F	N – I	L – F	L – I	F – I
1973	-.598	.581	-.874	-.001	-.069	163.740
1974	-1.410	.800	-1.206	.002	-.064	110.120
1975	-.998	.675	-1.058	-.005	-.066	399.027
1976	-.343	.506	-.751	-.001	-.072	154.381
1977	.055	.369	-.520	.002	-.082	98.532
1978	.137	.333	-.420	.009	-.086	46.709
1979	.196	.295	-.360	.010	-.093	43.012
1980	.199	.287	-.354	.008	-.091	52.153
1981	.199	.283	-.302	.022	-.097	23.095
1982	.167	.300	-.318	.019	-.086	26.445
1983	.099	.339	-.350	.021	-.075	24.482
1984	.050	.375	-.383	.026	-.074	18.765
1985	-.223	.512	-.547	.033	-.067	13.923
1986	-.187	.469	-.580	.013	-.067	36.768
1987	-.199	.481	-.576	.018	-.067	28.366
1988	-.100	.446	-.498	.022	-.068	22.162
1989	-.243	.520	-.546	.034	-.065	13.219
1990	-.183	.505	-.515	.039	-.069	11.222
1991	-.227	.515	-.525	.037	-.064	12.314
1992	-.323	.550	-.569	.036	-.061	12.332
1993	-.369	.559	-.603	.031	-.060	14.909
1994	-.422	.576	-.631	.030	-.059	15.342
1995	-.417	.573	-.628	.030	-.058	15.810

Note: N – L = Land-Labour, N – F = Land-Fertiliser, N – I = Land-Irrigation,
L – F = Labour-Fertiliser, L – I = Labour-Irrigation, F – I= Fertiliser-Irrigation

The extent of labour-fertiliser substitution showed a gradual increase over the latter period, while the substitution between fertiliser and irrigation showed a sustained decline over the latter period. The AES between labour and irrigation showed a decline over the latter years. Unlike the estimates of elasticity of substitution, the cross elasticity estimates are not symmetric. Hence, two tables are presented rather than one. The estimates of cross elasticities of input demand are given in Tables VI and VII. From these tables it is observed that there are considerable differences in sign and magnitude of estimates between the early years and latter years.

TABLE VI
ESTIMATED CROSS-ELASTICITIES OF INPUT DEMAND FOR THE HOMOTHETIC STRUCTURE, 1973 –1995

Year	N-L	N-F	N-I	L-F	L-I	F-I
1973	-0.4633	0.0058	-0.0065	0.0000	-0.0005	1.2117
1974	-1.1331	0.0098	-0.0089	0.0000	-0.0005	0.8149
1975	-0.7958	0.0043	-0.0073	0.0000	-0.0005	2.7533
1976	-0.2603	0.0052	-0.0057	0.0000	-0.0005	1.1733
1977	0.0394	0.0048	-0.0039	0.0000	-0.0006	0.7390
1978	0.0928	0.0063	-0.0047	0.0002	-0.0010	0.5185
1979	0.1281	0.0058	-0.0041	0.0002	-0.0011	0.4903
1980	0.1303	0.0051	-0.0045	0.0001	-0.0011	0.6571
1981	0.1238	0.0076	-0.0046	0.0006	-0.0015	0.3533
1982	0.1062	0.0076	-0.0062	0.0005	-0.0017	0.5183
1983	0.0642	0.0089	-0.0084	0.0005	-0.0018	0.5900
1984	0.0326	0.0113	-0.0089	0.0008	-0.0017	0.4372
1985	-0.1548	0.0179	-0.0118	0.0012	-0.0014	0.3007
1986	-0.1336	0.0100	-0.0104	0.0003	-0.0012	0.6581
1987	-0.1420	0.0117	-0.0107	0.0004	-0.0012	0.5248
1988	-0.0694	0.0123	-0.0105	0.0006	-0.0014	0.4676
1989	-0.1687	0.0187	-0.0126	0.0012	-0.0015	0.3054
1990	-0.1254	0.0198	-0.0113	0.0015	-0.0015	0.2458
1991	-0.1562	0.0192	-0.0130	0.0014	-0.0016	0.3041
1992	-0.2249	0.0206	-0.0144	0.0014	-0.0015	0.3132
1993	-0.2606	0.0189	-0.0148	0.0011	-0.0015	0.3668
1994	-0.3004	0.0193	-0.0154	0.0010	-0.0014	0.3743
1995	-0.2970	0.0188	-0.0155	0.0010	-0.0014	0.3905

TABLE VII

ESTIMATED CROSS-ELASTICITIES OF INPUT DEMAND FOR THE HOMOTHETIC STRUCTURE, 1973 –1995

Year	L – N	F – N	I – N	F – L	I – L	I – F
1973	-0.1239	0.1205	-0.1812	-0.0008	-0.0535	1.6374
1974	-0.2496	0.1416	-0.2135	0.0017	-0.0513	1.3435
1975	-0.1885	0.1276	-0.2000	-0.0041	-0.0523	2.5538
1976	-0.0765	0.1129	-0.1677	-0.0008	-0.0546	1.5901
1977	0.0148	0.0986	-0.1388	0.0011	-0.0588	1.2711
1978	0.0400	0.0972	-0.1227	0.0064	-0.0585	0.8781
1979	0.0615	0.0925	-0.1131	0.0068	-0.0607	0.8430
1980	0.0627	0.0905	-0.1116	0.0050	-0.0595	0.9283
1981	0.0668	0.0951	-0.1012	0.0134	-0.0606	0.6212
1982	0.0538	0.0965	-0.1021	0.0120	-0.0548	0.6664
1983	0.0299	0.1023	-0.1056	0.0133	-0.0487	0.6439
1984	0.0144	0.1089	-0.1113	0.0173	-0.0486	0.5648
1985	-0.0553	0.1272	-0.1358	0.0229	-0.0463	0.4873
1986	-0.0456	0.1149	-0.1419	0.0096	-0.0480	0.7832
1987	-0.0488	0.1178	-0.1412	0.0125	-0.0478	0.6893
1988	-0.0261	0.1158	-0.1295	0.0155	-0.0471	0.6117
1989	-0.0601	0.1286	-0.1350	0.0239	-0.0450	0.4759
1990	-0.0468	0.1289	-0.1314	0.0268	-0.0471	0.4388
1991	-0.0569	0.1289	-0.1315	0.0252	-0.0440	0.4605
1992	-0.0778	0.1325	-0.1370	0.0253	-0.0424	0.4612
1993	-0.0867	0.1313	-0.1418	0.0220	-0.0422	0.5054
1994	-0.0972	0.1328	-0.1453	0.0216	-0.0419	0.5124
1995	-0.0963	0.1322	-0.1448	0.0211	-0.0416	0.5201

Note: L – N = Labour–Land, F – N = Fertiliser–Land, I – N = Irrigation–Land,
F – L = Fertiliser–Labour, I – L = Irrigation–Labour, I – F = Irrigation–Fertiliser.

From Table VI, it is observed that significant changes have occurred over time. The cross elasticity of demand (ED) for fertiliser-irrigation has markedly declined over the latter years, but the ED for land-fertiliser, land-irrigation, labour-fertiliser and labour-irrigation displayed an increasing trend. Table VII also indicates that the ED for irrigation and fertiliser significantly declined but the magnitude differs from those in the earlier Table VI.

4.2 Estimates Based on the Non-homothetic Structure

The AES estimates for the period 1973-95 are reported in Table VIII. This table shows the changes in signs of AES between the earlier and latter period. Four of the six estimates of the absolute values of the AES show a declining tendency over the latter period. The substitution between fertiliser and irrigation has declined in the latter period. The land-labour pair showed a complementary relationship in the early period then they became substitute and again complement in the latter period. The land-fertiliser and labour-fertiliser substitutability showed evidence of an increasing tendency.

TABLE VIII

ESTIMATES OF ELASTICITIES OF SUBSTITUTION FOR THE NON-HOMOTHETIC STRUCTURE, 1973 – 1995

Year	N-L	N-F	N-I	L-F	L-I	F-I
1973	-0.798	0.146	-0.344	-0.009	-0.015	81.740
1974	-1.685	0.203	-0.478	-0.005	-0.014	55.027
1975	-1.238	0.151	-0.420	-0.013	-0.015	198.832
1976	-0.516	0.131	-0.293	-0.009	-0.016	77.088
1977	-0.065	0.107	-0.200	-0.008	-0.019	49.256
1978	0.036	0.114	-0.153	-0.001	-0.016	23.508
1979	0.108	0.105	-0.129	-0.001	-0.017	21.667
1980	0.112	0.099	-0.124	-0.003	-0.016	26.273
1981	0.123	0.117	-0.099	0.009	-0.014	11.763
1982	0.084	0.119	-0.097	0.007	-0.006	13.533
1983	0.004	0.133	-0.099	0.009	0.002	12.627
1984	-0.052	0.153	-0.113	0.015	0.001	9.714
1985	-0.362	0.209	-0.177	0.023	0.000	7.229
1986	-0.330	0.157	-0.199	0.004	-0.004	18.694
1987	-0.343	0.169	-0.196	0.008	-0.003	14.479
1988	-0.228	0.169	-0.160	0.013	-0.001	11.398
1989	-0.384	0.214	-0.173	0.025	0.002	6.892
1990	-0.316	0.218	-0.165	0.029	0.000	5.858
1991	-0.364	0.216	-0.161	0.027	0.004	6.451
1992	-0.471	0.228	-0.176	0.027	0.006	6.470
1993	-0.525	0.220	-0.190	0.022	0.005	7.774
1994	-0.584	0.224	-0.201	0.021	0.005	7.991
1995	-0.579	0.222	-0.199	0.020	0.005	8.234

The estimated cross elasticities of demand are presented in Tables IX and X. Both these tables also show considerable differences in signs and magnitudes from the previous structure. From Table IX, it is observed that the ED for fertiliser-irrigation and land-labour displayed a decreasing tendency whereas the land-fertiliser, land-irrigation and labour-fertiliser showed a rising tendency, in the latter years. Here the magnitude of the ED for labour-irrigation remained more or less the same during the entire period. Table X shows the pair of irrigation-fertiliser and labour-land, which also declined as the earlier table but differences exist in magnitudes.

TABLE IX

ESTIMATED CROSS-ELASTICITIES OF INPUT DEMAND FOR THE NON-HOMOTHETIC STRUCTURE, 1973 – 1995

Year	N-L	N-F	N-I	L-F	L-I	F-I
1973	-0.6185	0.0015	-0.0025	-0.0001	-0.0001	0.6049
1974	-1.3537	0.0025	-0.0035	-0.0001	-0.0001	0.4072
1975	-0.9878	0.0010	-0.0029	-0.0001	-0.0001	1.3719
1976	-0.3914	0.0013	-0.0022	-0.0001	-0.0001	0.5859
1977	-0.0464	0.0014	-0.0015	-0.0001	-0.0001	0.3694
1978	0.0245	0.0021	-0.0017	0.0000	-0.0002	0.2609
1979	0.0711	0.0021	-0.0015	0.0000	-0.0002	0.2470
1980	0.0735	0.0018	-0.0016	-0.0001	-0.0002	0.3310
1981	0.0763	0.0032	-0.0015	0.0003	-0.0002	0.1800
1982	0.0533	0.0030	-0.0019	0.0002	-0.0001	0.2652
1983	0.0029	0.0035	-0.0024	0.0002	0.0000	0.3043
1984	-0.0342	0.0046	-0.0026	0.0005	0.0000	0.2263
1985	-0.2516	0.0073	-0.0038	0.0008	0.0000	0.1562
1986	-0.2364	0.0033	-0.0036	0.0001	-0.0001	0.3346
1987	-0.2442	0.0041	-0.0036	0.0002	-0.0001	0.2679
1988	-0.1576	0.0047	-0.0034	0.0003	0.0000	0.2405
1989	-0.2662	0.0077	-0.0040	0.0009	0.0001	0.1592
1990	-0.2158	0.0085	-0.0036	0.0011	0.0000	0.1283
1991	-0.2505	0.0081	-0.0040	0.0010	0.0001	0.1593
1992	-0.3282	0.0085	-0.0045	0.0010	0.0001	0.1643
1993	-0.3706	0.0075	-0.0047	0.0007	0.0001	0.1912
1994	-0.4157	0.0075	-0.0049	0.0007	0.0001	0.1950
1995	-0.4120	0.0073	-0.0049	0.0007	0.0001	0.2034

TABLE X

ESTIMATED CROSS-ELASTICITIES OF INPUT DEMAND FOR THE NON-HOMOTHETIC STRUCTURE, 1973 – 1995

Year	L – N	F – N	I – N	F – L	I – L	I – F
1973	-0.1654	0.0303	-0.0712	-0.0069	-0.0118	0.8174
1974	-0.2982	0.0359	-0.0847	-0.0041	-0.0111	0.6713
1975	-0.2340	0.0286	-0.0793	-0.0100	-0.0118	1.2725
1976	-0.1150	0.0291	-0.0655	-0.0070	-0.0120	0.7940
1977	-0.0174	0.0286	-0.0535	-0.0055	-0.0134	0.6354
1978	0.0105	0.0332	-0.0447	-0.0005	-0.0109	0.4420
1979	0.0341	0.0330	-0.0405	-0.0004	-0.0114	0.4247
1980	0.0354	0.0311	-0.0392	-0.0022	-0.0102	0.4677
1981	0.0412	0.0394	-0.0333	0.0058	-0.0086	0.3164
1982	0.0270	0.0383	-0.0311	0.0045	-0.0039	0.3410
1983	0.0013	0.0402	-0.0300	0.0061	0.0011	0.3321
1984	-0.0152	0.0446	-0.0328	0.0101	0.0006	0.2924
1985	-0.0899	0.0519	-0.0440	0.0162	0.0002	0.2530
1986	-0.0808	0.0385	-0.0487	0.0030	-0.0029	0.3982
1987	-0.0839	0.0414	-0.0481	0.0059	-0.0024	0.3518
1988	-0.0592	0.0438	-0.0417	0.0087	-0.0004	0.3146
1989	-0.0949	0.0530	-0.0428	0.0171	0.0016	0.2481
1990	-0.0805	0.0556	-0.0420	0.0199	0.0001	0.2291
1991	-0.0913	0.0542	-0.0404	0.0183	0.0030	0.2413
1992	-0.1135	0.0548	-0.0423	0.0186	0.0040	0.2420
1993	-0.1233	0.0518	-0.0448	0.0154	0.0035	0.2635
1994	-0.1346	0.0516	-0.0463	0.0150	0.0035	0.2669
1995	-0.1336	0.0511	-0.0460	0.0145	0.0038	0.2709

Thus, from these estimates, it is found that considerable changes occurred in input relationships in Bangladesh agriculture over time. From this analysis, it can be noted that the AES between land and fertiliser (N-F) shows an increasing substitutability relationship and this increasing substitutability in agriculture would imply that the remarkable consumption of fertilisers is associated with the moderate increase in total cropped area. Besides this, the declining complementarity between land and irrigation is consistent with moderate increase in total cropped area and significant use of modern irrigation methods in Bangladesh agriculture.

The AES between labour and fertiliser (L-F) appeared as complements in the early years while in the latter years, it was found to be substitutes and its substitutability showed substantial fluctuations. This substitutability trend is compatible with the observed decrease of agricultural labour force and increased consumption of fertilisers.

The AES between fertiliser and irrigation (F-I) displayed substitutability throughout but very high degree substitutability showed significant decline over the years. It means that in the initial years farmers used more fertiliser than irrigation but over time both fertiliser and irrigation were used significantly and it might have caused the declining tendency of AES between fertiliser and irrigation. During the study period, the price of irrigation increased rapidly, but the increase of fertiliser price remained quite moderate compared to the irrigation. Consequently, farmers substituted relatively cheap chemical fertiliser for increasingly scarce and expensive land. Therefore, the use of chemical fertiliser increased remarkably over time.

The decreasing substitutability between fertiliser and irrigation (F-I) in agriculture would imply that the remarkable consumption of fertilisers is associated with the increasing application of more powerful, sophisticated and capital-intensive irrigation equipment. However, the adoption of both fertiliser and irrigation in Bangladesh agriculture happened may be due to the government measures which ensure the availability of agricultural inputs including fertiliser at the door steps of the farmers and utilisation and extension of the integrated technologies. Besides this, it can be mentioned that high irrigation cost can be alleviated to a great extent if more powerful and energy-efficient irrigation equipment is introduced for land, it may have caused the increasing use of irrigation by the farmers.

Of all the positive cross-price elasticities, the highest fertiliser-irrigation cross price elasticity is common among the two structures of the model, which implies that the demand for fertiliser was more responsive to the changes in the irrigation prices than that to other input prices but over time this responsiveness tended to decline.

V. CONCLUSIONS AND POLICY IMPLICATIONS

This study spans 23 years during which input prices and intensities changed. Considerable changes occurred in input relationship in Bangladesh agriculture over time. Differences exist in sign and magnitude of the values of AES and various cross price elasticities. In both the homothetic and non-homothetic structures, the AES between labour and fertiliser (L-F) appeared as complements in the early years, while in the latter years, it was found to be substitutes and these changes release labour force from the agricultural sector. Turning to the policy implications of these results, it is necessary that employment opportunity in the non-agricultural sector is created so that surplus labour from the agricultural sector is absorbed there. In this study, increasing substitutability between land and fertiliser (N-F) is observed and it is associated with the moderate increase in total cropped area. This suggests that proper utilisation of cultivable land might be ensured.

The highest degree of substitutability is obtained between fertiliser and irrigation (F-I), associated with the relatively high energy price which implies that farmers use more fertiliser and less irrigation. But use of more fertiliser has severe adverse effects on the soil. This suggests that it is essential to control the frequently use of fertiliser by developing the farmers awareness.

An issue of much concern in recent years is the increasing use of chemical fertilisers, especially nitrogen in agriculture. The use of nitrogen has severe adverse effects on the environment, such as rising levels of nitrates in some crops as well as in drinking water. So in order to save the environment, it is necessary that government take proper policy measures to ensure the supply of energy at reasonable price as well to spend enough money on research and development expenditure to produce energy-efficient farm machines so that farmers are interested to use more mechanical inputs and less biochemical inputs in the production process.

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