International Journal of Business and Management Invention (IJBMI)
ISSN (Online): 2319-8028, ISSN (Print):2319-801X
www.ijbmi.org || Volume 12 Issue 9 || September 2023 || PP 86-98

Determining Technical Efficiency in the Context of Crop Diversification in West Bengal during the Post Liberalization Era

Simanti Bandyopadhyay
Associate professor, Department of Economics, Victoria Institution (College), University of Calcutta

Date of Submission: 02-09-2023 Date of Acceptance: 13-09-2023

I. Introduction

Diversification is an integral part of the process of structural transformation of an economy. A deviation from agriculture towards industries and services denotes diversification (across sectors) at the macro level. However, within agriculture, diversification occurs between crops and across activities (i.e., between crop cultivation, livestock raising, forestry and fishing).The cultivation of different kinds of crops, like, minor crops, vegetables and fruits along with conventional major crops at farm level is referred to as horizontal crop diversification. On the contrary, vertical diversification occurs when farmers adopt some other enterprises, i.e., livestock rearing, poultry farming and fish farming at the farm level along with growing crops (Haque.T, 1996)

West Bengal is an important state in the eastern part of India in terms of agricultural production. It is predominantly an agrarian state covering 2.7 percent of India's geographical area while supporting nearly 8 percent of the country's population (India Population, 2017). During 2014-2015, West Bengal had a gross cropped area of 9.6 million hectares and contributed nearly 19 percent to the gross state domestic product (GSDP). This led the state contributing 9.73 percent to national output while covering 4.88 percent of net agrarian area. Agriculture still remains the most important means of livelihood of the rural masses in West Bengal. There are 7.12 million agricultural families in the state, 96 percent of whom are small and marginal farmers. The average size of land holding is less than one hectare. However, the state has diverse natural resources and varied agro climatic conditions that support the cultivation of a wide variety of crops.

West Bengal agriculture is observed to be diversifying towards cultivation of high value crops especially after economic liberalization. The small and the marginal farmers who dominate the agricultural scenario of the state, find that they can generate higher farm income and employment and mitigate risk by adopting a diversified crop profile (Vyas, 1996). The small and marginal farmers, depending on a small piece of land and having no alternative sources of employment and income try to cultivate as many crops as possible and choose high value crops including Boro paddy, oilseeds, potato, jute, fruits and vegetables, which after meeting their consumption needs can meet the requirements of their day-to-day living. Even the medium and large farmers practice crop diversification for the improvement of their living standard. The diverse natural resources and varied agro climatic conditions of West Bengal support the cultivation of a wide variety of crops. In terms of producing paddy and vegetables West Bengal ranks first and is the second largest producer of potato in the country. It is also the leading producer of jute, pineapple, litchi, mango, and loose flowers (https://wb.gov.in/portal/web/guest/agriculture). The cultivation of pulses, oilseeds, and maize in the state are also growing very fast.

Though the structure of agriculture in West Bengal in the post-liberalization era has undergone a change (Mithiya, et.al., 2018), a huge gap still exists between the demand and the production of crops like pulses, oilseeds, maize, and other agricultural commodities. A study on district wise technical efficiency of agricultural production in West Bengal in the context of crop diversification is, therefore, quite necessary to analyze how the existing gap between production and demand can be bridged.

The present study attempts to measure the Technical Efficiency (TE) of agricultural production in various farms of West Bengal in the perspective of crop diversification during the post-liberalization period. Here, for the sake of analysis, each district of the state has been considered a unit of production or in other words is identified as a farm.

The objective of the present study is

a) to measure crop diversification of different farms (district as a unit) in West Bengal after economic liberalization.

b) to estimate the levels of Technical Efficiency of different farms (district as a unit) in West Bengal during post-liberalization era.
c) to examine whether there exists any relationship between crop diversification and technical efficiency in West Bengal agriculture in the post liberalization era.

II. The Study Area

The study focuses on 17 major districts of West Bengal during 1990-91 to 2012-13. Due to non-availability of disaggregated data for both South and North Dinajpur from 1990-91 to 1995-96, the study has considered Dinajpur as a single district in the name of West Dinajpur. The district of Midnapore has been administratively divided after 2002. However, the agricultural division was done in the 1990s. So East Midnapore and West Midnapore have been considered separately. Alipurduar has emerged as an independent district in 2014, so it has been considered as a part of Jalpaiguri- its mother district. Similarly, Jhargram, East Bardhaman and West Bardhaman have been given recognition of independent districts in 2017. Hence Jhargram has been considered as a part of West Midnapore and East and West Bardhaman have been taken together as Bardhaman. Kalimpong has been considered as a part of its original district Darjeeling from where it was separated in 2017.

III. Method and Materials:

3.1 Data

The secondary data at district level and state level for West Bengal have been collected from different issues of "District Statistical Hand Book". The "State Domestic Product and District Domestic Product of West Bengal" published by Bureau of Applied Economics & Statistics, Department of Statistics & Programme Implementation, Government of West Bengal, have also been used as secondary data source. Data have also been taken from various issues of "Estimates of Area & Production of Principal crops in West Bengal" Evaluation Wing, Directorate of Agriculture, Government of West Bengal.

3.2 Methodology

A.1 Measuring Crop Diversification

There are quite a few methods that explain either concentration (i.e. specialization) or diversification of crop in a given time and space by a single indicator. Important ones include: Ogive Index (OI), Entropy Index (EI), Modified Entropy Index (MEI), Composite Entropy Index (CEI), Herfindahl Index and Simpson's Index (SID). However, the present study has used four of the measures which are as follows:

(i) The **Modified Entropy Index (MEI)** is defined as

MEI = $-\sum_i^N P_i \, log_N P_i$

MEI incorporates the number of crops as the base of the logarithm. The lower and upper values of MEI are 0 (total concentration) and 1 (perfect diversification).

(ii) The **Composite Entropy Index (CEI)** is

CEI = $-\sum_{i=1}^{N}(Pi \; log_N \; Pi\;)$* {1- (1/N)}

The value of the Composite Entropy Index increases with the decrease in concentration and rises with the number of crops . The value of CEI ranges from zero to one.

(iii) The **Herfindahl Index** is

HI = $\sum_{i=1}^{N} {p_i}^2$

This index was first used to measure the regional concentration of industries (Theil, 1967). The value of HI is bounded by 0 (perfect diversification) and 1 (complete specialization).

(iv) One very important measure of diversification is Simpson's Index (SID) which is defined as

SID = $1 - \sum_{i=1}^{N} Pi^2$

Pi is the proportionate area (or value) of the i^{th} crop activity in the gross cropped area (or the total value of output), while N is the number of crops. The Simpson's index ranges between 0 and 1. If there exists complete specialization, the index moves towards zero and away from zero implies diversification.

A.2 Cluster Analysis:

Clustering is the task of grouping similar objects in such a way that the objects in the same group have properties more similar to each other compared to those in other groups. In cluster analysis there are two types of clusters- non-hierarchical and hierarchical. In this study, hierarchical clustering has been used. Hierarchical clustering has further been divided into agglomerative and divisive clusters. In the present study, the districts are clustered by agglomerative clustering using **Ward's [i] method** based on the values of different crop diversification indices of different districts.

The loss of information is determined at each level of clustering, which is expressed as the increase of total sum of aberrance square of each cluster point from the average ESS value. Then it comes to a connection of clusters where there is a minimal increase in the errors of sum of squares (J. Han and M. Kamber,2006).
The accruement of ESS (Errors of Sum of Squares) function is calculated according to J. Han and M. Kamber, 2006:

$$\Delta ESS\left(A_i, A_j\right) = \frac{1}{2} d_{ES}\left(A_i, A_j\right),\ A_i, A_j \in o,$$

Where,

$$i, j = 1, 2, \cdots, n.$$

B. Measuring Technical Efficiency

Technically, a production function is efficient if a farm produces the maximum quantity of output attainable with given inputs. The production possibilities frontier is, therefore, the locus of the technically efficient input-output combinations. Inefficiency arises once a firm produces an output that is inside the production possibilities frontier. Technical efficiency thus refers to the ability of a farm to minimize input use in the production of a given output vector or the ability to obtain maximum output from a given input vector. In other words, a producer is technically efficient if an increase in an output leads to a reduction in at least one other output or an increase in at least one input, and if a reduction in any input causes an increase in at least one other input or a reduction in at least one output (Koopmans, 1951).

The shortfall of actual output from the potential one lying on the frontier is caused due to inefficiency and random shocks. This shortfall can be measured using stochastic frontier approach. The existence of inefficiency in crop production results from inefficient use of scarce resources. There exist two major competing methods for analyzing technical efficiency and its principal determinants, the parametric frontier (stochastic frontier approach) and the non-parametric frontier (data envelopment analysis). The non-parametric frontier suffers from the criticism that it takes no account of the possible influence of random shocks like measurement errors and other noises in the data (Coelli, 1996).

The parametric frontier uses econometric method to estimate the parameters of both stochastic frontier production function and inefficiency effect model. The biggest advantage of stochastic frontier approach is the introduction of stochastic random noises that are beyond the control of the farmers in addition to the inefficiency effects. The disadvantage of this approach is that it imposes explicit restriction on functional forms for the production function and distributional assumption for one-sided error term (Battese and Coelli,1995). As opposed to the stochastic frontier method, the data envelopment analysis is a deterministic frontier, meaning that all deviations from the frontier is attributed to inefficiency alone. It is difficult to accept this assumption given the inherent variability of agricultural production in developing countries due to a lot of exogenous factors like weather shocks, pests, disease, etc. (Battese and Coelli,1995). Under these circumstances, the present study finds the stochastic frontier approach introduced by Aigner et.al (1977), and Meeusen and Van den Broeck (1977) more suitable to measure technical efficiency in agricultural production.

B.1 Theoretical Model

Technical Efficiency in an agricultural farm is measured as the ratio between the observed output and the stochastic frontier output (potential output) under the assumption of fixed input (or, alternatively, as the ratio between the observed input and the minimum input under the assumption of fixed output). The stochastic frontier output is the potential output possible given the available technology and inputs used. In stochastic frontier analysis, all deviations from potential output are attributed to inefficiency. However, sometimes potential output might itself fall due to exogenous shocks. As a result, the production frontier might shift inwards. The stochastic frontier output is given by

$$Y_i^* = f(X_i;\ \beta_i).\exp(v_i) \qquad (1)$$

The actual output is given by

$$Y = f(X_i;\ \beta_i).\exp(v_i).\exp(-u_i) \quad ; \quad v_i \leq 0 \quad \text{and} \quad u_i \geq 0 \qquad (2)$$

$f(X_i;\ \beta_i)$,exp (v_i), exp$(-u_i)$ and $f(X;\ \beta)$.exp(v) are a deterministic kernel, an effect of exogenous shocks on output, inefficiency and stochastic frontier respectively.
The error term is composed of two terms: a symmetric disturbance v_i that is independently and identically distributed (IID) as N $(0, \delta_v{}^2)$ representing the random fluctuations beyond farmers' control; the inefficiencies of the farmers are captured by the other term $u_{i,}$ that is independent of v_i and is independently and identically distributed as N $(\mu, \delta_v{}^2)$
By definition,

$$TE = Y_i/Y_i^* \qquad 0 \leq TE \leq 1 \qquad (3)$$

$= f(X_i; \beta_i).\exp(v_i).\exp(-u_i)/ f(X_i; \beta_i).\exp(v_i)$

$= \exp(-u_i) \quad ; \quad u_i \geq 0$

$= e^{-u_i}$

Therefore,

$Y_i = Y_i^*. \, TE = f(X_i; \beta_i).\exp(v_i).TE$

$= f(X_i; \beta_i).\exp(v_i - u_i)$ ___________ (4)

$(v_i - u_i)$ is the composite error term

Where, the u_i is the inefficiency term that always lies between 0 and 1.When u_i is equal to zero, TE =1, the production is then on the frontier and the farm is technically efficient. When u_i is greater than zero ($u_i > 0$) the farm is technically inefficient (TE<1) since production takes place inside the frontier.

The stochastic frontier production function (4) is defined for cross-sectional data. Pitt and Lee (1981) estimated a stochastic frontier production function using panel data of N firms over T periods. The model has been defined as follows:

$Y_{it} = f(X_{it}; \beta).\exp(v_{it} - u_{it});$ ____________(5)

Where, $(v_{it} - u_{it})$ is the composite error term i= 1, 2, ..., N, t = 1, 2, ... , T

HereY_{it} represents the production of the i-th firm (i =1,2,...,N) at the t-th period (t = 1,2,..., T); X_{it} is a (1 x k) vector of values of inputs and other explanatory variables associated with the i-th firm at the t-th period, β is a vector of unknown parameters for the stochastic frontier analysis. v_{it}s are assumed to be iid N (0, σ_v^2) random errors and independent of u_{it}s. The u_{it}s represent non-negative random variables associated with technical inefficiency of production and are assumed to be independently distributed.

Since agricultural production always operates under uncertainty, the present study employs the stochastic production frontier approach discussed above. In this framework it has been assumed that u_{it}s are non-negative random variables which are responsible for technical inefficiency in agricultural production. u_{it}s specify the inefficiency effects in the stochastic frontier production function due to factors under farmers' control.

As for the choice of the distributional form of the one-sided error term, given that there is no justification for the selection of any particular distribution, three distributional forms—half-normal, truncated normal and exponential can be used in the estimation of the model. However, the present study has restricted itself to half-normal and truncated normal distribution to estimate inefficiency.

In the panel data extension, the production function is specified as follows:

$Y_{it} = ß_0 + \sum ß_{jit} X_{it} + v_{it} - u_{it}$ .... (6)

Where, Y_{it} is the natural logarithm of the production of agricultural farm i at time t, X_{it} is the vector of the natural logarithms of the inputs to be included in the analysis, $ß_j$ is the vector of the parameters to be estimated, v_{it} is the idiosyncratic error and u_{it} is a time-varying panel-level effect. If a time-invariant specification is selected then:

$u_{it} = u_i$ ui □ $N^+(\mu, \delta_v{}^2)$, vi □ $N^+(0, \delta_v{}^2)$

Time plays an important role in influencing production inefficiency. Battese and Coelli (1992) proposed a simple model that can be used to estimate the time behavior of inefficiency:

$u_{it} = \{\exp[-\eta(t-T)]\}u_i$

Where, η is an unknown scalar parameter to be estimated, which determines whether inefficiency is time-varying or time-invariant, and u_i s are assumed to be iid and truncated at zero of the N (μ, σ_u^2) distribution.

If η is positive, then– $\eta(t-T) = \eta(T-t)$ is positive for $t<T$ and so, $\exp[-\eta(t-T)] > 1$, which implies that technical inefficiency of farm declines over time. If η is zero, technical inefficiency of agricultural farm remains constant; if it is negative, it increases over time.

Choosing between a half-normal and a truncated normal distribution is the most important exercise for the inefficiency analysis undertaken in the study. The half-normal distribution is a special case of the truncated normal distribution, and implicitly involves the restriction H_0: μ = 0. Here the log-likelihood ratio of the half-normal distribution is that of the null hypothesis, while the log-likelihood ratio of truncated normal distribution is that of the alternative hypothesis. The hypothesis that efficiency is invariant over time (i.e.$\eta=0$) will be tested. The hypothesis is tested first assuming inefficiency as time variant, then the SFA is done restricting inefficiency as time invariant.

Parameters of the stochastic frontier given by equation (5) are estimated by using maximum likelihood estimation. The likelihood function expressed in terms of variance parameters are:

$\sigma^2 = \sigma^2_v + \sigma^2_u$ *and* $\gamma = \sigma^2_u / \sigma^2$

Here γ (Gama) is the parameter that measures the discrepancy between the frontier and observed levels of output. This is interpreted as the total deviation of observed output levels from their frontier values attributable to technical inefficiency. γ has a value between zero and one.

$\sigma_u{}^2$ is the variance parameter that denotes deviation from the frontier due to inefficiency;

$\sigma_v{}^2$is the variance parameter that denotes deviation from the frontier due to noise or external shock;

$\sigma^2$is the variance parameter that denotes the total deviation from the frontier**.**

B.2. Empirical Model

Maximum Likelihood Estimation technique has been used in estimating stochastic frontier production function. The Cobb-Douglas and Trans-log production functions are used in stochastic frontier production analysis to estimate inefficiency. The analysis is based on data of 17 production units for the period of 24 years. The stochastic frontier production function in (5) can be viewed as a linearised version of the logarithm of the Cobb-Douglas production function and the Trans-log production function for panel data:

Cobb-Douglus

$$\ln (Y_{it}) = \beta_0 + \beta_1 \ln (L_{it}) + \beta_2 \ln (HL_{it}) + \beta_3 \ln (F_{it}) + \beta_4 \ln (IR_{it}) + \beta_5 \ln (Cr_{it}) + \varepsilon_{it} \qquad (7)$$

Trans-log production function

$$\ln (Y_{it}) = \beta_0 + \beta_1 \ln (L_{it}) + \beta_2 \ln (HL_{it}) + \beta_3 \ln (F_{it}) + \beta_4 \ln (IR_{it}) + \beta_5 \ln (Cr_{it}) + \beta_6 \ln (L_{it}) \ln (L_{it}) + \beta_7 \ln (HL_{it}) \ln (HL_{it}) + \beta_8 \ln (F_{it}) \ln (F_{it}) + \beta_9 \ln (IR_{it}) \ln (IR_{it}) + \beta_{10} \ln (L_{it}) \ln (HL_{it}) + \beta_{11} \ln (L_{it}) \ln (F_{it}) + \beta_{12} \ln (L_{it}) \ln (IR_{it}) + \beta_{13} \ln (HL_{it}) \ln (F_{it}) + \beta_{14} \ln (HL_{it}) \ln (IR_{it}) + \beta_{15} \ln (F_{it}) \ln (IR_{it}) + \varepsilon_{it} \qquad (8)$$

$\varepsilon_{it} = v_{it} - u_{it}$, $u_{it} \geq 0$ $\quad$ i = 1, 2,.....,N,t = 1, 2, T

Y_{it} represents the quantity of output (in 000' tons) of the i-th unit in year t,
'L_{it}' represents cultivated land (in 000' hectares) of the i-th unit in year t,
'HL_{it}' represents the total human labor (in 000' man-days) of the i-th unit in year t,
'IR_{it}' represents cultivated land under irrigation (in 000' hectares) of the i-th unit in year t,
'F_{it}' represents the quantity of fertilizer used (in 000' tons of NPK) of the i-th unit in year t,
'Cr_{it}' represents Credit facilities (Dummy used as a proxy variable) of the i-th unit in year t,
u_{it} -non-negative time-variant random variables capturing technical inefficiency,
v_{it} -random variables of i-th unit in year t reflecting effect of noise (factors not under farmers' control)

The Trans-log frontier is susceptible to multicollinearity even if it is a more flexible form (Thiam et.al, 2001). The study has observed the presence of high mulicollinearity[ii] between independent variables for the data collected for the sake of analysis. Hence, in the present study the Cobb-Douglas frontier has been preferred over the Trans-log one.

IV. Results and Discussion:

4.1 Pattern of Crop Diversification in West Bengal using Cluster Analysis

In the standard literature a certain magnitude of crop diversification is randomly selected and set as a benchmark to determine the hierarchical position of the districts. The districts are categorized in terms of magnitudes crop diversification in relation to this set value. However, the cluster analysis categorizes the districts in a more scientific way in terms of their respective magnitudes of crop diversification.

On the basis of the magnitudes of selected crop diversification indices (Annexure table 1 to table 3), an attempt has been made to cluster the districts to find out the trend and pattern of crop diversification during different sub periods under study**.** There are five hierarchical clusters in this study which are presented in Table 1 based on dendrogram (Annexure Figure1 to Annexure Figure 3). Nadia, Murshidabad and Malda always belong to cluster I, that is, the excellent category in terms of diversification while Purulia remains in cluster V, i.e., the lowest category, throughout the period under study. The district of South 24 Parganas, was in cluster V, i.e., the lowest category in sub-period I but shifted to the cluster IV (moderate group) in the subsequent two sub-periods. This implies that South 24 Parganas has slowly moved up over time.
The district of West Dinajpur was in cluster III in sub-period I but interestingly moved up to the cluster II during the two subsequent sub periods. The district of Jalpaiguri has shifted from cluster III in sub period I to cluster II in Sub period II and finally to cluster I in sub periods III.

Table: 1 Categorization of Districts according to Diversification during 1990-91 to 2012-13

	Diversification	TE 1992-93	TE 2002-03	TE 2012-13
Cluster	Value	Name of the Districts	Name of the Districts	Name of the Districts
Cluster I	Excellent	Nadia, Murshidabad, Malda	Nadia, Murshidabad, Malda	Nadia, Murshidabad, North 24 Pargans, Jalpaiguri, Malda,
Cluster II	Very High	North 24 Parganas, Hooghly, Darjeeling, Coochbihar,	North 24Pargans, Jalpaiguri, Hooghly, Darjeeling, Coochbihar, West Dinajpur	Coochbihar, Hooghly, Darjeeling, West Dinajpur,
Cluster III	Moderately High	Jalpaiguri, Burdwan, West Dinajpur	Burdwan, Howrah, West Midnapore, Birbhum	Burdwan, Birbhum, Howrah, West Midnapore

Cluster IV	Moderate	Birbhum, West Midnapore, Howrah, Bankura, East Midnapore,	East Midnapore, Bankura, South 24 Parganas	Bankura, East Midnapore, South 24 Parganas
Cluster V	Very Low	South 24 Parganas, Purulia	Purulia	Purulia

Source: Author's calculation

It is interesting to note that though the districts of West Dinajpur and Jalpaiguri have both moved up in the crop diversification ladder from sub period I to Sub period III but the pace of movement of Jalpaiguri is much faster than that of West Dinajpur. Similarly, North 24 Parganas was in cluster II during first two sub periods but shifted to cluster I during the next sub periods.

Darjeeling, Coochbihar and Hooghly remains in cluster II (Very high category of diversification) throughout the study period and Bardhaman has continued to remain in cluster III. Bankura and East Midnapore have all along remained in cluster IV in all the study periods. Howrah and West Midnapore started with moderate diversification (i.e., cluster IV) in sub period I but shifted to moderately high category (i.e., cluster III) during the next two sub periods. Bankura and East Midnapore have always remained in cluster IV.

4.2 Estimation of Stochastic Frontier Production Function:

Under Stochastic Frontier approach, either Cobb Douglus or Trans-log production function can be used for measuring technical efficiency. However, the use of Trans-log production function leads to the problem of multicollinearity between independent variables that may influence the regression results. The existence of high multicollinearity can be observed from the values of the Variance Inflation Factor (VIF) and the corresponding low values of Tolerance. In the present study it has been observed that the values of the VIF are extremely high for Trans-log production function vis-à-vis Cobb Douglas production function (See Table 2 in the Annexure for the values of VIF and Tolerance). Hence, the Cobb Douglas production function has been chosen for measuring technical efficiency.

Maximum likelihood estimation of the parameters of Cobb-Douglas stochastic frontier production function given by equation (7) have been obtained using Frontier version 4.1 (Coelli, 1996) software. Estimates of parameters as well as the SE and t ratio of the Maximum Likelihood estimation of agricultural farms of West Bengal have been presented in Tables 2, 3.

The maximum-likelihood estimates of the parameters for time-variant and time-invariant Cobb-Douglas stochastic frontier production function with the assumptions of half normal and truncated normal distribution are presented in Tables 2 and 3. The half-normal and a truncated- normal distributions have been considered to measure the presence of inefficiency in the model. Here, the log-likelihood ratio of the half-normal distribution is the null hypothesis (H_0: $\mu = 0$), while the log-likelihood ratio of the truncated normal distribution is the alternative hypothesis (H_1:$\mu \neq 0$). Similarly, another hypothesis that inefficiency is time-invariant (i.e., η=0) will be tested. The model will be estimated first by assuming time-variant (i.e.,$\eta \neq$0) inefficiency; then restricted by modeling the frontier as time-invariant (Hasan, et. al., 2012).

The estimates of the parameters with time-varying inefficiency effects for truncated and half-normal distributions are presented in Table 2.

The results depict that the coefficients in both the half normal and the truncated normal distribution in the time-variant model are 0.420 and 0.464 for land, 0.336 and 0.306 for labor, 0.055 and 0.052 for irrigation, 0.102 and 0.088for fertilizer,0.284 and 0.277 for credit, respectively. The estimated parameters for all the inputs (variables) are positive. The coefficients of the inputs have signs as expected which confirm the expected positive relationship between land, labor, fertilizer, irrigation and credit with agricultural production. All these coefficients are statistically significant. The estimated values of the parameters of Cobb-Douglas frontier production function obtained with the assumptions of truncated and half-normal distributions are almost similar.

Table 2: Stochastic Frontier Production Function Operate withTime-Variant

		Half Normal Distribution			Truncated Normal Distribution		
Variables	Parameter	Coefficients	SE	T-value	Coefficients	SE	T-value
Constant	β_0	0.641	0.681	0.941	0.83	0.747	1.111
Ln Land	β_1	0.42	0.141	2.97	0.464	0.145	3.193
Ln Labor	β_2	0.336	0.13	2.571	0.306	0.138	2.211
Ln Irrigation	β_3	0.055	0.025	2.201	0.052	0.028	1.899
Ln Fertilizer	β_4	0.102	0.036	3.323	0.088	0.034	2.643
Ln Credit	β_5	0.284	0.032	8.812	0.277	0.029	9.721
Sigma Squared	σ^2	0.115	0.038	3.006	0.052	0.018	4.495
Gama	γ	0.708	0.1	7.025	0.418	0.082	5.067

Sigma	σ	0.339			0.228		
Mu	*μ*	N			0.297	0.079	3.741
Eta	*H*	0.045	0.006	7.454	0.0398	0.005	7.681
Log likelihood Function		79.613			83.988		
LR ratio		8.75					

*, **,*** Significance level at 1 per cent, 5 per cent and 10 per cent, S.E = Standard Error, Source: Authors' Calculation

The log likelihood functional values also are 79.61 and 83.98 in half normal distribution and truncated normal distribution respectively which are very close to each other. For a truncated normal distribution, γ is estimated to be 0.418 and for a half-normal distribution it is 0.708. Both the values are positive and significant. It can be interpreted that 41.80 percent variation in farm output of West Bengal agriculture is due to the differences in technical inefficiency when truncated normal distribution is considered and 70.80 percent variation arises when half-normal distribution is chosen. From Table 2, we can also say that the estimates of σ are 0.339 and 0.2228 for half-normal and truncated normal distribution respectively with a time-variant model, which are significantly positive indicating that the assumptions of truncated and half-normal distributions are correct.

The results in Table 3 show that the maximum-likelihood estimates of the parameters with time-in variant inefficiency effects for half-normal and truncated normal distributions are 0.504 and 0.573 for land, 0.222 and 0.165 for labor, 0.114 and 0.112 for irrigation, 0.156 and 0.154 for fertilizer, 0.512and 0.509 for credit, respectively. The signs of the coefficients of all inputs are positive. All these coefficients in both the distribution are statistically significant. The log likelihood functional values of the two distributions are 39.745and 46.133, which are nearly similar. The values of γ are found to be positive and significant in both the cases of half-normal and truncated normal distributions with time-invariant model and the values are 0.839 and 0.525 respectively. Therefore, we can say that in the case of time-invariant model 52.5 percent

Table 3: Stochastic Frontier Production Function Operate with Time-invariant

		Half Normal Distribution			Truncated Normal Distribution		
Variables	Parameter	Coefficients	SE	T-value	Coefficients	SE	T-value
Constant	β_0	0.731	0.861	0.849	1.004	1.016	0.988
Ln Land	β_1	0.504*	0.155	3.262	0.573*	0.170	3.363
Ln Labor	β_2	0.222**	0.149	1.492	0.165***	0.175	0.941
Ln Irrigation	β_3	0.114*	0.027	4.171	0.112*	0.027	4.108
Ln Fertilizer	β_4	0.156*	0.033	4.665	0.154*	0.035	4.449
Ln Credit	β_5	0.512*	0.025	20.487	0.509*	0.025	20.26
Sigma Squared	σ^2	0.259*	0.092	2.792	0.084*	0.012	6.872
Gama	γ	0.839*	0.059	14.112	0.525*	0.062	8.498
Sigma	σ	0.508			0.289		
Mu	*μ*	-	-	-	0.421	0.096	4.405
Eta	*H*	-	-	-	-	-	-
Log likelihood Function		**39.745 (μ=η =0)**			**46.13 3 (η= 0 , μ ≠ 0)**		
LR Ratio		**12.776**					

*,**,*** Significance level at 1 per cent, 5 per cent and 10 per cent, S.E = Standard Error, Source: Authors' Calculation

variation in farm output of West Bengal agriculture is due to the differences in technical inefficiency when the distribution is truncated normal while 83.9 percent variation is found when half-normal distribution is considered. Table 3 also depicts that the estimates of σ are 0.508 and 0.289 for half-normal and truncated normal distribution respectively in the time-invariant model, which are significantly positive.

The null hypothesis of the model is that there is no technical inefficiency effect. In other words,

H_0: $\sigma_u^2 = 0$ and the alternative hypothesis is H_1: $\sigma_u^2 > 0$.

A number of test statistics are available for testing this hypothesis. Here, the Generalized Likelihood-Ratio test has been selected for testing alternative hypothesis. i.e.,

H_0: $\gamma = 0$ and the alternative hypothesis is H_1: $\gamma > 0$ (with $\gamma = \sigma_u^2 / \sigma^2$ where, $\sigma^2 = \sigma_u^2 + \sigma_v^2$)

A series of formal hypothesis tests have been conducted to work out the distribution of random variables related to the existence of technical inefficiency and also the residual error term. These are tested through imposing restrictions on the model and the generalized likelihood-ratio statistics have been used to determine the significance of the restrictions. The generalized likelihood ratio statistic defined by the test, requires the estimation of the model under both the null and the alternative hypothesis. Under the null hypothesis, the model is equivalent to the traditional average response function, without the technical inefficiency effect, u_i. Following hypotheses can be tested using the generalized likelihood ratio test: LR = -2[$L(H_0)$ - $L(H_1)$], where $L(H_0)$ and $L(H_1)$ are the values of log likelihood functions under the null and alterative hypothesis, respectively (Greene, 1980). The null hypothesis is rejected when the calculated chi-square is greater than the critical chi-square with degree of freedom (the number of parameters equal to zero at null hypothesis) at 1%, 5% or 10% level of significance, i.e., LR > χC2 (Kodde and Palm, 1986).Test Statistic is calculated in Frontier and the critical value of a test of size $\alpha_{0,05}$ is 2.7.

If the null hypothesis involves $\gamma = 0$, expressing that the technical inefficiency effects are not present in the model, then, λ has a mixed chi-square distribution with the number of degrees of freedom given by the number of restrictions imposed (Battese and Coelli,1993) because $\gamma = 0$ is a value on the boundary of the parameter space for λ. If the parameter μ is restricted to zero then the half-normal distribution is the effective model for inefficiency. On the other hand if η is restricted to zero in the model then the model is one with time-invariant inefficiency effect.

Table 4 shows that all the values of test statistics are more than their critical values. It implies that all the null hypotheses are rejected and the alternative hypotheses are accepted. In our study, γ is always greater than zero and statistically significant whatever be the hypothesis. Therefore, inefficiency exists in the agricultural production of West Bengal.

Table 4: Test of Hypothesis for the parameters of the Stochastic Frontier Production Function

Null Hypothesis	Log Likelihood Function	Alternative Hypothesis	Log Likelihood Function	Test statistics	Critical Value	Decision
$H_0: \mu = 0\ \eta = 0$	39.745	$H_a: \mu \neq 0\ \eta = 0$	46.133	12.776	2.706	Rejected
$H_0: \mu = 0, \eta \neq 0$	79.613	$H_a: \mu \neq 0 \eta \neq 0,$	83.988	8.75	5.138	Rejected
$H_0: \mu \neq 0 \eta = 0,$	46.133	$H_a: \mu \neq 0 \eta \neq 0,$	83.988	75.694	5.138	Rejected

Notes: All critical values are at 5% level of significance. The critical value for this test involving γ=0 is obtained from table of Kodde and Palm (1986).

Source: Authors' Calculation

We also tried to check the robustness of the result by using maximum likelihood function instead of the ordinary least square. The hypothesis $\mu = 0$, is rejected, which means half-normal distribution is not suitable for our analysis. The alternative distribution of a truncated normal is the effective distribution for our analysis. Similarly, η positive is the accepted proposition in our model. Therefore it can be said that the maximum-likelihood estimates of the Cobb-Douglas stochastic frontier production function in a time-variant truncated normal distribution is the suitable model for the measurement of technical inefficiency in West Bengal agriculture. The estimates for the parameters of the time-varying inefficiency model in Table 3 indicate that the estimates for η parameter in a truncated normal distribution is positive and significant, the technical efficiency tends to increase over time and vice-versa. The variance ratio(Gama) shows that 41.80 percent of the differences between the observed output and the frontier level of output has been caused by differences in farm's technical inefficiencies, while the remaining variation is due to factors out of farmers' control.

4.3 Farm Level Technical Efficiency

Table 5 indicates that the average technical efficiency of different agricultural production units (districts) of West Bengal have increased over the time periods considered. In the decade of 2010, all the production units have produced more efficiently than in the previous decades. The magnitude of technical efficiency of all the districts is more than 0.599 during the decade of 2010. Among these production units, Hooghly shows the highest technical efficiency and Purulia exhibits the lowest efficiency during triennium 1992-93, 2002-03 and 2012-13. The mean efficiencies are 0.478, 0.609 and 0.719 during the triennium ending 1992-93, 2002-03 and 2012-13 respectively.

Table 5: **Decade-wise Average Efficiency of Agricultural Production Units in West Bengal.**

Units	Triennium Ending1992-93	Triennium Ending 2002-03	Triennium Ending 2012-13
Hooghly	0.980	0.986	0.991
Bardhaman	0.679	0.775	0.846
Paschim Midnapore	0.596	0.711	0.799
Bankura	0.581	0.700	0.791
Birbhum	0.461	0.601	0.716
Darjeeling	0.460	0.600	0.715
Murshidabad	0.449	0.590	0.707
North 24 Parganas	0.448	0.589	0.706
Howrah	0.431	0.575	0.695
Purba Midnapore	0.424	0.569	0.690
Nadia	0.423	0.568	0.690
Coochbihar	0.404	0.551	0.676
Malda	0.380	0.529	0.658

Jalpaiguri	0.377	0.527	0.656
West Dinajpur	0.370	0.520	0.651
South 24 Parganas	0.355	0.506	0.639
Purulia	0.306	0.459	0.599
Mean Efficiency	0.478	0.609	0.719

Source: Authors' Calculation

The table 5 also indicates that during triennium ending 1993-94, the magnitude of technical efficiency of all the farms are below 0.60, except Hooghly (0.980) and Bardhaman (0.679). Fifteen farms out of seventeen have shown low levels of technical efficiency during this period. In other words, 88.23 percent of farms have technical efficiency below 0.60. However, the value of technical efficiency of all farms during triennium ending 2013-14, are above 0.60. In this period all farms show comparatively higher level of technical efficiency.

V. Technical Efficiency vis-à-vis Crop Diversification

It will now be attempted to analyze whether there is any significant association between technical efficiency and crop diversification during the three consecutive sub periods under study. Since the present study centers around crop diversification and technical efficiency in West Bengal during the post liberalization era, the specific association between crop diversification and technical efficiency is extremely essential to be determined.

Here, in this section the attempt is to investigate the one to one relationship between technical efficiency and crop diversification using the simple statistical correlation. The correlation coefficient is a statistical tool widely used in economics as well as in other disciplines of study to quantify the association between two variables. The variables chosen in this section are crop diversification and technical efficiency.

Table 6: Correlation coefficient between Technical Efficiency and Crop Diversification during 1990-91 to 2012-13

	Crop Diversification during Triennium ending 92-93	**Crop Diversification during Triennium ending 02-03**	**Crop Diversification during Triennium ending 12-13**
TE During Triennium ending 92-93	0.773**	NA	NA
TE during Triennium ending 02-03	NA	0.761**	NA
TE during Triennium ending 12-13	NA	NA	0.761**

*at 1% level of significance

In Table 6 the correlation coefficient between crop diversification and technical efficiency during triennium ending 1992-93 is found to be 0.773 which is highly statistically significant. This implies that there is a strong positive association between crop diversification and technical efficiency. In other words, this means crop diversification enhances technical efficiency. In the subsequent sub period, that is, during triennium ending 2002-03 the correlation coefficient between crop diversification and technical efficiency is observed to be 0.761 which continues to remain statistically significant implying that the high degree of correspondence between crop diversification and technical efficiency still persists. During the final sub period under analysis, that is, during triennium ending 2012-13, the correlation coefficient between crop diversification and technical efficiency has remained unchanged at 0.761 compared to the previous sub period (triennium ending 2002-03). Hence, the technical efficiency and crop diversification remained highly statistically correlated throughout the study period. The analysis indicates towards the fact that crop diversification in agriculture enhances technical efficiency.

VI. Conclusion

The study uses both descriptive and econometric methods of data analysis to examine the trend and pattern of crop diversification and the extent of technical efficiency at the farm level(district as a unit) in West Bengal during the post liberalization era and to see the relationship between the two. The Hierarchical Cluster Analysis has been used to rank the districts in terms of crop diversification on the basis of Simpson's index. In measuring Technical Efficiency the Stochastic Frontier approach has been used as the analytical tool. Hypotheses tests confirm the appropriateness of Cobb-Douglas frontier over Trans-log frontier for the analysis of data; the specificity of using stochastic frontier production function over convectional production function; the joint statistical significance of inefficiency effects; the appropriateness of using truncated-normal distribution over half normal distribution for one sided error term; and the increasing returns to scale nature of the stochastic frontier production function.

In this study, the district level crop diversification and technical efficiency in West Bengal have been analyzed for the post-liberalization period from 1990-91 to 2012-13. It has also been attempted to check the robustness of the results under alternative specifications by using maximum likelihood function instead of ordinary least square. The findings indicate that the truncated normal distribution with time-variant model is suitable for the measurement of technical inefficiency for West Bengal agriculture. The estimated variance ratio indicates that around 48.90 percent of the differences between the observed output and the estimated output has been caused by differences in farms' technical inefficiencies, while the remaining variation is due to factors beyond farmers' control. The technical efficiencies of different production units have increased over time. Among the production units (districts in this study) Hooghly shows the highest technical efficiency while Purulia exhibits the lowest efficiency. The study finds that during all the three sub periods under consideration, there is high positive correlation between crop diversification and technical efficiency for West Bengal. Hence it can be concluded that to reap the benefit of technical efficiency, more crop diversification should be practiced in West Bengal. It also observes that the sum of the coefficients of inputs in the production function (Cobb-Douglas) is greater than one implying the presence of increasing returns to scale in West Bengal agriculture.

References:

[1]. Aigner, D., Lovell, C. K., & Schmidt, P. (1977). Formulation and estimation of stochastic frontier production function models. Journal of econometrics, 6(1), 21-37.

[2]. Battese, G. E., and Coelli, T. J. (1992). Frontier Production Functions, Technical Efficiency and Panel Data: with Application to Paddy Farmers in India, Journal of Productivity Analysis, 3, 153-169.

[3]. Battese, G.E., and Coelli, T.J.(1993). A Stochastic Frontier Production Function Incorporating a Model for Technical Inefficiency Effects. Department of Econometrics. University of New England.

[4]. Battese, G. E., and Coelli, T. J.(1995). A Model for Technical Inefficiency Effects in a Stochastic Frontier Production Function for Panel Data. Empirical Economics. Volume 20, Issue 2, pp.325–332.

[5]. Battese, G.E., and Coelli, T.J.(1993). A Stochastic Frontier Production Function Incorporating a Model for Technical Inefficiency Effects. Department of Econometrics. University of New England.

[6]. Coelli, T.J.(1996). A Guide to Frontier, Version 4.1: A Computer Program for Stochastic Frontier Production and Cost Function Estimation, CEPA Working Paper, No.7/96, Department of Econometrics, University of New England, Armidale, Australia.

[7]. Govt. of West Bengal. (1990-91 to 2013-14). Estimates of Area & Production of Principal Crops in West Bengal, Evaluation Wing, Directorate of Agriculture, Government of West Bengal, Various issues**.**

[8]. Govt. of West Bengal. (1990-91 to 2013-14).District Statistical Hand Books, Bureau of Applied Economics and Statistics, Government of West Bengal, Various issues.

[9]. Govt. of West Bengal. District Statistical Hand Books. Bureau of Applied Economics and Statistics, Government of West Bengal, Various issues (1990-91 to 2013-14).

[10]. Govt. of West Bengal. Estimates of Area & Production of Principal Crops in West Bengal. Evaluation Wing, Directorate of Agriculture, Government of West Bengal, Various issues (1990-91 to 2013-14).

[11]. Greene, W. H. (1980). Maximum likelihood estimation of econometric frontier functions. Journal of econometrics, 13(1), 27-56.

[12]. Haque T (1996). Diversification of small farms in India: Problems and Prospects. Ed: T. Haque. National Centre for Agriculture Economics and Policy Research, New Delhi.

[13]. Hasan, Md. Zobaer, Kamil Anton Abdulbasah, Mustafa Adli, and Baten Md. Azizul.(2012). Stochastic Frontier Model Approach for Measuring Stock Market Efficiency with Different Distributions, PLOS/ ONE, Retrieved fromhttps://doi.org/10.1371/journal.pone.0037047

[14]. India Population-2017. Population of West Bengal- 2017 Retrieved fromhttp://indiapopulation2017.in/population-of-west-bengal2017.html

[15]. J. Bacher, A. Poge and K. Wenzig, (2010) , "Cluster analyse— An wendungsorientierteEinfuhrung in Klassifikationsverfahren," Oldenbourg, Munchen, p. 432. doi:10.1524/9783486710236 [Citation Time(s):1]

[16]. J. Han and M. Kamber, "Data Mining—Concepts and Techniques," MK Publisher, San Francisco, 2006, p. 772. [Citation Time(s):2]

[17]. Kodde, David A. and Palm, Franz C. Wald.(1986). Criteria for Jointly Testing Equality and Inequality Restrictions, Econometrica, 54 (5), pp. 1243-1248.

[18]. Koopmans, T.C.(1951).An analysis of Production as Efficient Combination of Activities. In Activity Analysis of Production and Allocation, Koopmans, T.C., eds, Cowles Commission for Research in Economics, Monograph no. 13. New York

[19]. Meeusen, W., & van Den Broeck, J. (1977). Efficiency estimation from Cobb-Douglas production functions with composed error. International economic review, 435-444.

[20]. Mithiya Debasis, Mandal Kumarjit and Bandyopadhyay Simanti.(2018). Diversification towards horticulture as a source of income and employment in West Bengal, International Journal of Current Research, 10 (7), pp. 71996-72004.

[21]. Pitt, M. and Lee, L. (1981). The Measurement and Sources of Technical Efficiency in the Indonesian Weaving Industry. Journal of Development Economics, 9, 43-64.

[22]. Theil H (1967). Economics and Information Theory, North Holland.

[23]. Thiam, A., Bravo-Ureta, B. E., & Rivas, T. E. (2001). Technical efficiency in developing country agriculture: a meta-analysis. Agricultural economics, 25(2-3), 235-243.

[24]. Vyas V S (1996). Diversification in Agriculture: Concept, Rationale and Approaches, Indian Journal of Agricultural Economics, 51(4), pp. 636-43.

Annexure: able :1 Magnitude of Crop Diversification of Different Districts in West Bengal during TE **1992-93**

Districts	Si	HI	Districts	MEI	Districts	CEI
Nadia	0.839	0.161	Nadia	0.967	Nadia	0.829
Murshidabad	0.806	0.194	Malda	0.910	Malda	0.780
Malda	0.795	0.205	Murshidabad	0.872	Murshidabad	0.763
North 24 Parganas	0.707	0.293	Darjeeling	0.768	North 24 Parganas	0.647
Coochbihar	0.707	0.293	Hooghly	0.754	Hooglhy	0.646
Hooghly	0.701	0.299	North 24 Parganas	0.740	Coochbihar	0.641
Darjeling	0.690	0.310	Coochbihar	0.732	Darjeling	0.640
West Bengal	0.654	0.346	West Bengal	0.695	West Bengal	0.617
West Dinajpur	0.628	0.372	West Dinajpur	0.684	West Dinajpur	0.598
Jalpaiguri	0.605	0.395	Bardhaman	0.627	Bardhaman	0.538
Bardhaman	0.581	0.419	Jalpaiguri	0.606	Jalpaiguri	0.530
Howrah	0.563	0.437	Howrah	0.572	Paschim Midnapore	0.486
Purba Midnapore	0.533	0.467	Purba Midnapore	0.556	Howrah	0.477
Paschim Midnapore	0.524	0.476	Paschim Midnapore	0.555	Purba Midnapore	0.477
Bankura	0.486	0.514	Birbhum	0.523	Bankura	0.454
Birbhum	0.451	0.549	Bankura	0.518	Birbhum	0.448
Purulia	0.284	0.716	Purulia	0.314	Purulia	0.275
South24 Parganas	0.263	0.737	South24 Parganas	0.274	South24 Parganas	0.240

Table :2 Magnitude of Crop Diversification of Different Districts in West Bengal during TE 2002—03

Districts	SI	HI	Districts	MEI	Districts	CEI
Nadia	0.856	0.144	Nadia	0.964	Nadia	0.843
Murshidabad	0.847	0.153	Murshidabad	0.917	Murshidabad	0.816
Malda	0.818	0.182	Malda	0.908	Malda	0.795
North 24 Parganas	0.798	0.202	Darjeling	0.835	North 24 Parganas	0.739
Darjeling	0.798	0.202	North 24 Parganas	0.831	Jalpaiguri	0.736
Jalpaiguri	0.795	0.205	Jalpaiguri	0.818	Darjeling	0.730
Hooghly	0.780	0.220	Hooghly	0.812	Hooghly	0.711
West Bengal	0.751	0.249	West Bengal	0.773	West Bengal	0.695
West Dinajpur	0.741	0.259	West Dinajpur	0.765	West Dinajpur	0.680
Cochbihar	0.717	0.283	Cochbihar	0.753	Cochbihar	0.669
Howrah	0.682	0.318	Howrah	0.715	Howrah	0.613
Bardhaman	0.679	0.321	Bardhaman	0.694	Bardhaman	0.607
Paschim Midnapore	0.646	0.354	Birbhum	0.677	Paschim Midnapore	0.596
Birbhum	0.627	0.373	Paschim Midnapore	0.672	Birbhum	0.592
Purba Midnapore	0.625	0.375	Purba Midnapore	0.625	Purba Midnapore	0.546
Bankura	0.577	0.423	Bankura	0.590	Bankura	0.525
South24 Parganas	0.522	0.478	South24 Parganas	0.575	South24 Parganas	0.444
Purulia	0.389	0.611	Purulia	0.391	Purulia	0.348

Table 3: Magnitude of Crop Diversification of Different Districts in West Bengal during TE 2012-13

Districts	SI	HI	Districts	MEI	Districts	CEI
Nadia	0.859	0.141	Nadia	0.966	Nadia	0.846
Murshidabad	0.843	0.157	Murshidabad	0.902	Murshidabad	0.802
North 24 Parganas	0.810	0.190	Malda	0.885	Malda	0.774
Malda	0.803	0.197	North 24 Parganas	0.839	Jalpaiguri	0.749
Jalpaiguri	0.802	0.198	Darjeling	0.835	North 24 Parganas	0.746
Darjeling	0.798	0.202	Jalpaiguri	0.832	Darjeling	0.731
Hooghly	0.775	0.225	Hooghly	0.802	West Dinajpur	0.706
West Dinajpur	0.756	0.244	West Dinajpur	0.794	Hooghly	0.702
West Bengal	0.753	0.247	West Bengal	0.774	West Bengal	0.696
Cochbihar	0.729	0.271	Cochbihar	0.756	Cochbihar	0.670
Howrah	0.681	0.319	Howrah	0.719	Howrah	0.617
Paschim Midnapore	0.675	0.325	Birbhum	0.677	Paschim Midnapore	0.593
Bardhaman	0.649	0.351	Paschim Midnapore	0.668	Birbhum	0.592
Purba Midnapore	0.629	0.371	Bardhaman	0.657	Bardhaman	0.575
Birbhum	0.628	0.372	Purba Midnapore	0.629	Purba Midnapore	0.551
Bankura	0.600	0.400	Bankura	0.598	Bankura	0.531
South24 Parganas	0.500	0.425	South24 Parganas	0.562	South24 Parganas	0.499
Purulia	0.346	0.654	Purulia	0.339	Purulia	0.301

Dendrogram for Cluster Analysis

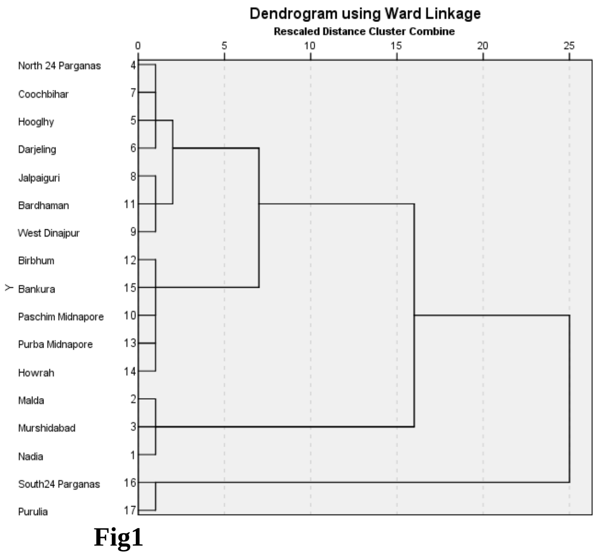

Fig1

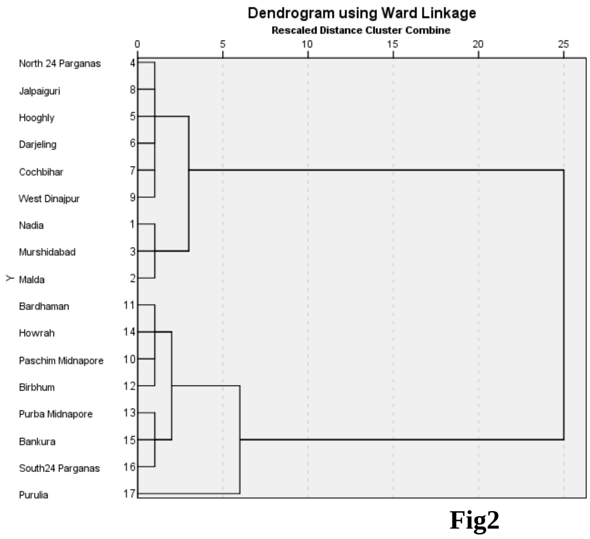

Fig2

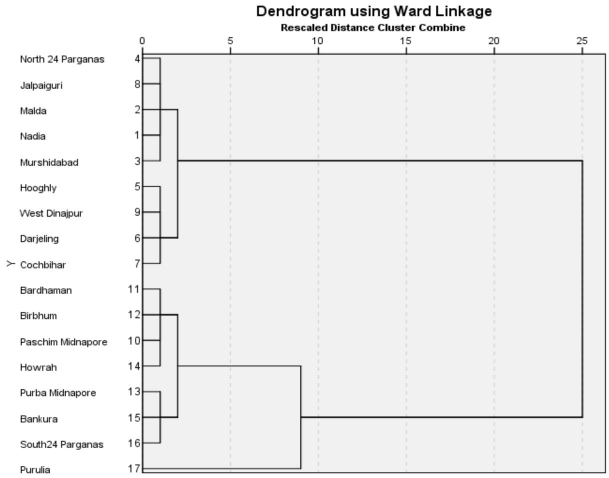

Fig3

---

i **Ward's method** is also marked as a method of minimizing the increases of errors of sum squares. It is based on optimizing the homogeneity of clusters according to the criteria of minimizing the increase of errors of sum squares of deviation points from centroid. This is the reason why this method is different from other methods of hierarchical clustering, which are based on optimization of the distance between clusters (J. Bacher, A. Poge and K. Wenzig, 2010).

ii The presence of multicolinearity in the data can be observed from the values of the Variance Inflation factor (VIF) and the corresponding values of Tolerance. Available literature suggests that the values of VIF greater than 5 and the corresponding values of tolerance less than 0.25 imply that the independent variables are highly correlated. The collinearity statistics between independent variables in the study presented in (Annexure Table 4) shows the presence of high multicollinearity for tran-slog production function

Table 4: Calculation of Tolerance and VIF under Cobb Douglas and Trans-log Production Function

	Collinearity Statistics			
	Trans-log		Cobb Douglas	
Variables	Tolerance	VIF	Tolerance	VIF
LN Land	0.0011	893.417	0.317	3.699
LN Labour	0.0161	62.153	.0293	4.879
LN Irrigation	0.0016	608.380	0.355	2.817
LN Fertilizer	0.0030	338.424	0.480	2.081
LN Land ^{2}	0.0003	3008.927	0.807	1.239
LN Labour^2	0.00008	11829.25373		
LN Irrigation ^{2}	0.0041	245.392		
LN Fertilizer ^{2}	0.0036	279.917		
LN Land Labour	0.00003	30171.28834		
LN Land Irrigation	0.0003	2957.748		
LN Land Fertiliser	0.0005	1843.798		
LN Labour Irrigation	0.00007	15243.80452		
LN LabourFertiliser	0.00004	28508.23122		
LN Irrigation Fertiliser	0.0015	653.088		
Agricultural Credit	0.7102	1.408		

a Dependent Variable: Production