

Measuring Agricultural Crop Production Efficiency due to Climates and Hydrology in Bangladesh: An Application of Stochastic Frontier Model

Mohammed Amir Hamjah
B.Sc. (Honors), MS (Thesis) in Statistics
Shahjalal University of Science and Technology, Sylhet-3114, Bangladesh
Email: arif.stat.sust@hotmail.com

Abstract
The main objective of this study is to develop a Cobb-Douglas Stochastic Frontier Production model to measure the different types of agricultural crop production's efficiency in Bangladesh due to climates and hydrology. Climatic and hydrological information is divided into two season named as dry season which covers the months October, November, December, January and February, and summer season which covers the months March, April, May, June, July, August and September considering the climatic condition of Bangladesh. From the study, it is obtained that mean efficiency of the rice and cereal production are 0.9203 and 0.97385 respectively. There is a little opportunity to increase production to achieve maximum production by increasing technology. At the same time jute, potato, cereal and species get the maximum frontier production with mean efficiency approximately equal to one and it also implies there is no need any technological advancement and inefficiency occurs due to stochastic noise.
Keywords: Agricultural production, Climates, Hydrology, Efficiency, Stochastic Frontier Model

1. Introductions

1.1. Statement of the Problems

Agriculture is always vulnerable to unfavorable weather events and climate conditions in the world as well as in Bangladesh. Despite technological advances such as improved crop varieties and irrigation systems, weather and climate are important factors, which play a significant role to agricultural productivity. The impacts of climate change on agriculture food production are global concerns as well as in matter Bangladesh, where lives and livelihoods depend mainly on agriculture, is exposed to a great danger, as the country is one of the most vulnerable countries due to climate change.

1.2. Background of the Study

Bangladesh has a large agrarian base country with 76% of total population is living in the rural areas and 90% of the rural population directly related with agriculture. Agriculture is the single largest producing sector of the economy since it comprises about 18.6% (data released on November, 2010) of the country's GDP and employs around 45% of the total labor force. Considering the climatic conditions. In agricultural sector 48.1 percent of the country's labor force is always vulnerable to changing climate conditions and unfavorable weather events. The sector is already under pressure for increasing food demand, problems associated with agricultural land and water resource depletion. The issues of climate change make the pressure more acute for the sector.

1.3. Climates and Agriculture

Climate change and agriculture are interrelated processes, both of which take place on a global scale. Global warming is projected to have significant impacts on conditions affecting agriculture, including temperature, carbon dioxide, glacial run-off, precipitation and the interaction of these elements. These conditions determine the carrying capacity of the biosphere to produce enough food for the human population and domesticated animals. The overall effect of climate change on agriculture will depend on the balance of these effects. Climate is the primary determinant of agricultural productivity. Concern over the potential effects of long-term climate change on agriculture has motivated a substantial body of a research over the past decade. This body of research addresses possible physical effects of climate changes on agriculture such as changes in crop and livestock yields, as well as the economic consequences of these potential yield changes.

2. Review of Literature

Mohammed Amir Hamjah (2014) has conducted an analysis to measure the climatic effects on Cotton and Tea production in Bangladesh by using Multiple Regression Model and here he also measure the production efficiency due to climates using Stochastic Frontier Model. He has shown that there are huge opportunity to increase Cotton production by increasing Technology to get maximum productions and Tea achieves maximum productions. Rahman, Mia and Bhuiyan (2012) has conducted in the year 2008-2009 to estimate the farm-size-specific productivity and technical efficiency fall rice crops. Farm-size-specific technical efficiency scores were estimated using stochastic production frontiers. There were wide of variations of productivity among farms, where large farms exhibited the highest productivity. The lowest net return or the highest cost of production was accrued from both the highest wage rate and highest amount of labour used in medium farms. Muhammad Fauzi Makki, Yudi Ferrianta, Rifiana and Suslinawati (2012) has conducted a study in Indonesia to evaluate the impact of climate change on productivity and technical efficiency paddy farms in tidal swamp land The analysis showed Impact on productivity have not good because negative. Paulo Dutra Constantin and Diogenes Leiva Martin (2009) was conducted a study to apply a Cobb-Douglas Translog Stochastic Production Function and Data Envelopment Analysis in order to estimate inefficiencies over time as well as respective TFP (Total Factor Productivity) sources for main Brazilian grain crops namely, rice, beans, maize, soybeans and wheat - throughout the most recent data available comprising the period 2001-2006. Hasan et al.(2012) is measured bank efficiency in Malaysia using Cobb Douglas Stochastic Frontier Model. Huynh Viet Khai and Mitsuyasu Yabe(2011) measure the technical inefficiency of rice production in Vietnam.

3. Objective of the study

The main objective of this study is to develop a Stochastic Frontier model for measuring the agricultural production efficiency in Bangladesh due to climates. The specific objective of this study is to develop a Stochastic Frontier model of Cobb-Douglas type for measuring the agricultural production efficiency of different types of major crops named as Rice, Jute, Vegetable, cereal, Species and Potato covering the area Bangladesh due to climates and hydrology.

4. Data source and Data manipulation

The climatic data sets are available from the Bangladesh Government's authorized organization named as BARC (Bangladesh Agricultural Research Council) websites www.barc.gov.bd. The crop data sets are also available from Bangladesh Agricultural Ministry's websites named as www.moa.gov.bd. These data set are available from 1972 to 2006. Climatic and Hydrological information was in the original form such that it is arranged in the monthly average information corresponding to the years from 1972 to 2006 according to the 30 climatic stations. The name of these stations are Dinajpur, Rangpur, Rajshahi, Bogra, Mymensingh, Sylhet, Srimangal, Ishurdi, Dhaka, Comilla, Chandpur, Josser, Faridpur, Madaripur, Khulna, Satkhira, Barisal, Bhola, Feni, MaijdeeCourt, Hatiya, Sitakunda, Sandwip, Chittagong, Kutubdia, Cox's Bazar, Teknaf, Rangamati, Patuakhali, Khepupara, Tangail, and Mongla. We take the month October, November, December, January and February as a "dry season" and March, April, May, June, July, August, September as a "summer season" considering the weather and climatic conditions of Bangladesh. Then, finally we take average seasonal climatic information of 30 climatic station corresponding to the year from 1972 to 2006. We take the average of 30 climatic area because of focusing the overall country's situation and overall model fitting for whole Bangladesh.

5. Used Software

This analysis has completely done by open source Software for statistical data analysis named as **R** for windows (version **2.15.1**). The additional library packages used for analysis is **"frontier"**.

6. Methodology

6.1. *The Production Frontier: Theoretical Framework*

The standard definition of a production function is that it gives the maximum possible output for a given set of inputs, the production function therefore defines a boundary or a frontier. All the production units on the frontier will be fully efficient. Efficiency can be of two kinds: technical and allocative. Technical efficiency is defined either as producing the maximum level of output given inputs or as using the minimum level of inputs given output Allocative efficiency occurs when the marginal rate of substitution between any of the inputs equals the corresponding input price ratio. If this equality is not satisfied, it means that the country is not using its inputs in the optimal productions. An initial justification for computing efficiency can be found in that its measure facilitates comparisons across economic units. Secondly, and perhaps more importantly, when divergence in efficiency is found some further research needs to be undertaken to understand which factors led to it. Finally, differences in efficiency show that there is scope for implementing policies addressed to reduce them and to improve efficiency. A production frontier model can be written as

$$y_i = f(x_i;\ \beta)\ TE_i \tag{1}$$

where, y_i is the output of producer i (i = 1, 2,… ,N); x_i is a vector of M inputs used by producer i; $f(x_i;\ \beta)$ is the production frontier and β is a vector of technology parameters to be estimated. Let TE_i be the technical efficiency of producer i,

$$TE_i = \frac{y_i}{f(x_i;\ \beta)} \tag{2}$$

In the case, $TE_i = 1$, y_i achieves its maximum feasible output of $f(x_i;\ \beta)$. If $TE_i < 1$, it measures technical inefficiency in the sense that observed output is below the maximum feasible output. The production frontier

$f(x_i;\ \beta)$ is deterministic. That means that the entire shortfall of observed output y_i from maximum feasible output $f(x_i;\ \beta)$ is attributed to technical inefficiency. Such a specification ignores the producerspecific random shocks that are not under the control of the producer. We have to specify the stochastic production frontier

$$y_i = f(x_i;\ \beta)\exp(v_i)\,TE_i \tag{3}$$

where, $f(x_i;\ \beta)\exp(v_i)$ is the stochastic frontier, which consists of a deterministic part $f(x_i;\ \beta)$ common to all producers and a producer-specific part which $\exp(v_i)$ captures the effect of the random shocks to each producer TE_i can be computed for Stocahastic Fromntier production of ith producer

$$TE_i = \frac{y_i}{f(x_i;\ \beta)\exp(v_i)} \tag{4}$$

Technical efficiency can be estimated using either the deterministic production frontier model given by equations (1) and (2), or the stochastic frontier model given by equations (3) and (4). Since the stochastic frontier model includes the effect of random shocks on the production process, this model is preferred to the deterministic frontier.

6.2. ***Stochastic Frontier Productions Function***

The econometric approach to estimate frontier models uses a parametric representation of technology along with a two-part composed error term. Under the assumption that is of $f(x_i;\ \beta)$ is of Cobb-Douglas type, the stochastic frontier model in equation (5) can be written as

$$Y_i = \alpha + \beta X_i + \varepsilon_i \tag{5}$$

where, ε_i is an error term with $\varepsilon_i = v_i - u_i$

The economic logic behind this specification is that the production process is subject to two economically distinguishable random disturbances: statistical noise represented by v_i and technical inefficiency represented by u_i

There are some assumptions necessary on the characteristics of these components. The errors v_i are assumed to have a symmetric distribution, in particular, they are independently and identically distributed as N $(0, \sigma_v^2)$. The component u_i is assumed to be distributed independently of v_i and to satisfy $u_i \geq 0$ (e.g. it follows a one-sided normal distribution $N^+(0, \sigma_v^2)$. The non-negativity of the technical inefficiency term reflects the fact that if $u_i > 0$ the country will not produce at the maximum attainable level. Any deviation below the frontier is the result of factors partly under the production unit's control, but the frontier itself can randomly vary across firms, or over time for the same production unit. This last consideration allows the assertion that the frontier is stochastic, with a random disturbance v_i being positive or negative depending on favorable or unfavorable external events.

It is important to note that given the non-negativity assumption on the efficiency term, its distribution is non-normal and therefore the total error term is asymmetric and non-normal. This implies that the least squares estimator is inefficient. Assuming that v_i and u_i are distributed independently of x_i, estimation of (5) by OLS provides consistent estimators of all parameters but the intercept, since $E(\varepsilon_i) = -E(u_i) \leq 0$. Moreover, OLS does not provide an estimate of producer-specific technical efficiency. However, it can be used to perform a simple test based on the skewness of empirical distribution of the estimated residuals. Schmidt and Lin (1984) propose the test statistic

$$b^{1/2} = \frac{m_3}{m_2^{3/2}} \tag{6}$$

where, m_2 and m_3 are the second and the third moments of the empirical distribution of the residuals. Since v_i is symmetrically distributed, m_3 is simply the third moment of the distribution of u_i.

The case $m_3 < 0$ implies that OLS residuals are negatively skewed, and that there is evidence of technical inefficiency. In fact, if $u_i > 0$ then $\varepsilon_i = v_i - u_i$ is negatively skewed. The positive skewness in the OLS residuals, i.e. $m3 > 0$, suggests that the model is mis-specified. Coelli (1995) proposed an alternative test statistic

$$b^{1/2} = \frac{m_3}{(6m_2^3/N)^{1/2}} \tag{7}$$

Where, N is equal to the number of observations. Under the null hypothesis of zero skewness in the OLS residuals, $m_3=0$, the third moment of OLS residuals is asymptotically distributed as a normal random variable with mean zero and variance

$6m_2^3/N$. This implies that the test statistic (7) is asymptotically distributed as a standard normal random variable N (0,1).

Coelli (1995) presents Monte Carlo experiments where these tests have the correct size and good power. The asymmetry of the distribution of the error term is a central feature of the model. The degree of asymmetry can be represented by the following parameter:

$$\lambda = \frac{{\sigma_u}^2}{{\sigma_v}^2} \quad (8)$$

The larger λ is, the more pronounced the asymmetry will be. On the other hand, if λ is equal to zero, then the symmetric error component dominates the one-side error component in the determination of ε_i. Therefore, the complete error term is explained by the random disturbance v_i, which follows a normal distribution. ε_i therefore has a normal distribution. To test the hypothesis that λ = 0, we can compute a Wald statistic or likelihood ratio test both based on the maximum likelihood estimator of λ Coelli (1995) tests as equivalent hypothesis γ = 0 against the alternative γ > 0, where

$$\gamma = \frac{{\sigma_u}^2}{{\sigma_u}^2 + {\sigma_v}^2} \quad (9)$$

A value of zero for the parameter γ indicates that the deviations from the frontier are entirely due to noise, while a value of one would indicate that all deviations are due to technical inefficiency. The Wald statistic is calculated as

$$W = \frac{\hat{\gamma}}{\widehat{\sigma_\gamma}} \quad (10)$$

Where, $\hat{\gamma}$ is maximum likelihood estimate of γ and $\widehat{\sigma_\gamma}$ is its estimated standard error. Under H_0: γ = 0 is true, the test statistic is asymptotically distributed as a standard normal random variable. However, given that γ cannot be negative, the test is performed as a one-sided test. The likelihood test statistic is

$$LR = -2[Log(L_0) - Log(L_1)] \quad (11)$$

Where, log (L_0) is the log-likelihood valued under the null hypothesis and log (L_1) is the log-likelihood value under the alternative. This test statistic is asymptotically distributed as chi-square random variable with degrees of freedom equal to the number of restrictions. Coelli (1995) notes that under the null hypothesis γ = 0, the statistic lies on the limit of the parameter space since γ cannot be less than zero. He therefore concludes that the likelihood ratio statistic will have an asymptotic distribution equal to a mixture of chi-square distributions ($\frac{1}{2}\chi_0^2 + \frac{1}{2}\chi_1^2$).

7. Climatic and Hydrological Variables Used in This Study

sun.sum = Sunshine of the Summer Season, sun.dry = Sunshine of the Dry Season , clo.sum = Cloud Coverage of the Summer Season, clo.dry = Cloud Coverage of the Dry Season, max.tem.dry = Maximum Temperature of the Dry Season, max.tem.sum = Maximum Temperature of the Summer Season, min.tem.dry = Minimum Temperature of the Dry Season, min.tem.sum = Minimum Temperature of the Summer Season, rain.dry= Ammount of Rainfall of the Dry Season, rain.sum= Amount Rainfall of the Summer Season, rh.dry = Relative Humidity of the Dry Season, rh.sum= Relative Humidity of the Summer Season, wind.dry = Wind Speed of the Dry Season and wind.sum = Wind Speed of The Summer Season.

8. Stochastic Frontier Modeling for Crop Production (Results and Discussion)

8.1. *Measuring Efficiency of Rice Production*

The parameter estimates of the Cobb-Douglas Stochastic Frontier model of rice production is given in the Table 1.

Table 1: Summary Statistics of Rice Production Model

Coefficients	**Estimate**	**Std. Error**	**z value**	**Pr(>|z|)**
(Intercept)	-5.2815614	0.9980079	-5.2921	<0.0001
sun.sum	-1.1612254	0.8252752	-1.4071	0.159405
sun.dry	-0.6905965	0.6955296	-0.9929	0.320755
clo.sum	0.3292201	0.6650524	0.495	0.62058
clo.dry	-0.1211959	0.2333886	-0.5193	0.60356
max.tem.dry	1.4115718	0.9238623	1.5279	0.126537
max.tem.sum	5.951248	0.9638423	6.1745	<.00001
min.tem.dry	-0.6551029	0.8892407	-0.7367	0.461305
min.tem.sum	-2.4853962	0.8752185	-2.8397	0.004515
rain.dry	0.064013	0.0402981	1.5885	0.112177
rain.sum	0.0698809	0.1339579	0.5217	0.601905
rh.dry	0.2569688	1.0179759	0.2524	0.800708
rh.sum	0.2154085	1.0146	0.2123	0.831866
wind.dry	-0.3551979	0.3772969	-0.9414	0.346486
wind.sum	-0.5709867	0.3693081	-1.5461	0.122081
sigmaSq	0.0107692	0.0026116	4.1236	0.000037
gamma	0.997475	0.0523128	19.0675	<0.00001

From the Table 1, it is clear that max.tem.sum and min.tem.sum have statistically significant effects on frontier rice production due to Climates and hydrology covering the whole county Bangladesh at 1% level of significance.

From the fitted model, Average Technical Efficiency is 0.9203. The highest value of the efficiency is 0.99727, which occurred in the year 2000 and the lowest is 0.72164, which occurred in the year 1972. These results indicate that the majority of year are relatively well in achieving maximum rice production. Efficiency rate 92% gives sense that most of the year can achieve maximum rice productions. At the same time, according to the Coelli's test $H_0: \gamma = 0$, gives the value of gamma is 0.997475≈1 and it's p-value for testing the hypothesis is < 0.0001 indicates highly insignificant and all of the deviations are arisen due to technical inefficiency. It also means that there is a little opportunity to increase rice production in the Bangladesh by increasing technology. Again, from the likelihood ratio test, the $Pr(|\chi^2_{(1)}| \geq 4.8703) = 0.0356$, which implies to reject the null hypothesis that there is no production inefficiency, that is, there exist inefficiency of rice production due to climates and hydrology in Banglaedsh.

8.2. *Measuring Efficiency of Jute Production*

The parameter estimates of the Cobb-Douglas Stochastic Frontier model of jute production is given in the Table-2

Table 2: Summary Statistics of Jute Production Model

Coefficients	**Estimate**	**Std. Error**	**z value**	**Pr(>|z|)**
(Intercept)	0.3523773	3.2503584	0.1084	0.913669
sun.sum	-1.6188726	0.7563736	-2.1403	0.032330
sun.dry	0.9681135	0.6313227	1.5335	0.12516
clo.sum	0.2401076	0.9745043	0.2464	0.805381
clo.dry	-0.2141151	0.3233916	-0.6621	0.507912
max.tem.dry	-13.5346061	3.232654	-4.1868	0.000028
max.tem.sum	16.9917757	3.4567849	4.9155	<0.00001
min.tem.dry	9.5593806	1.8386826	5.199	<0.00001
min.tem.sum	-9.2011897	3.2809713	-2.8044	0.005041
rain.dry	-0.1338877	0.0762369	-1.7562	0.079053
rain.sum	-0.0393865	0.25176	-0.1564	0.875683
rh.dry	-1.5469571	1.4621969	-1.058	0.29007
rh.sum	1.106362	2.1387951	0.5173	0.604959
wind.dry	0.4133963	0.3406668	1.2135	0.224942
wind.sum	0.1671995	0.3550161	0.471	0.637667
sigmaSq	0.0129934	0.0041963	3.0964	0.001959
gamma	0.0016255	0.3252627	0.005	0.996013

From the Table 2, it is transparent that sun.sum, max.tem.sum, max.tem.dry, min.tem.dry and min.tem.sum have statistically significant effects on frontier Jute production due to Climates and hydrology covering the whole county Bangladesh at 5% level of significance.

From the fitted model, Average Technical Efficiency is 0.9963437. The highest value of the efficiency is 0.9964942, which occurred in the year 1986 and the lowest is 0.9961876, which occurred in the year 1975. These result indicate all of the year are relatively well in achieving maximum Jute production. Efficiency rate approximately 100% indicates that all of the year achieve maximum Jute productions. At the same time, according to the Coelli's test $H_0: \gamma = 0$, gives the value of gamma is 0.0016255 and it's p-value = 0.996013 indicates highly insignificance and all of the deviations arisen due to stochastic noise. It will also mean that there is no opportunity to increase jute productions in the Bangladesh by increasing technology and the country achieve maximum production due to climates. Again, from the likelihood ratio test, the $\Pr(|\chi^2_{(1)}| \geq 0)$ 0.4997, which implies that there is no technical inefficiency of the jute production due to climates and hydrology at 5% level of significance.

8.3. Measuring Efficiency of Potato Production

The parameter estimates of the Cobb-Douglas Stochastic Frontier model of potato production is given in the Table 3

Table 3: Summary Statistics of Potato Production Model

Coefficients	**Estimate**	**Std. Error**	**z value**	**Pr(>|z|)**
(Intercept)	-8.32832	2.52613	-3.2969	0.0009777
sun.sum	1.04129	0.72046	1.4453	0.1483686
sun.dry	-0.61811	0.54339	-1.1375	0.2553298
clo.sum	2.37787	0.84182	2.8247	0.0047327
clo.dry	-0.12916	0.34881	-0.3703	0.711168
max.tem.dry	7.89217	3.16553	2.4932	0.0126611
max.tem.sum	0.09486	3.37394	0.0281	0.9775695
min.tem.dry	-4.51443	1.85774	-2.4301	0.0150962
min.tem.sum	7.86292	2.40660	3.2672	0.0010860
rain.dry	0.07130	0.07341	0.9713	0.3314021
rain.sum	0.66290	0.28730	2.3073	0.0210373
rh.dry	1.82872	1.21784	1.5016	0.1331983
rh.sum	-8.79558	1.85938	-4.7304	0.0000024
wind.dry	-0.45035	0.42333	-1.0638	0.2874095
wind.sum	-1.25643	0.42190	-2.9781	0.0029008
sigmaSq	0.02091	0.00505	4.1419	0.0000344
gamma	0.00001	0.01820	0.0005	0.9995697

From the Table 3, it is clear that clo.sum, max.tem.dry, min.tem.dry, min.tem.dry, rain.sum, rh.sum and rain.sum have statistically significant effects on frontier Potato production due to Climates and Hydrology covering the whole county Bangladesh at 2% level of significance.

Again from the fitted Stochastic Frontier model, Average Technical Efficiency is 0.9996387. The highest value of the efficiency is 0.9996399, which occurred in the year 2005 and the lowest is 0.9996378, which occurred in the year 1998. These result indicate that all of the year are relatively well in achieving maximum potato productions in Bangladesh due to climates and hydrology. Efficiency rate approximately 100% percent gives sense that all of the year achieve maximum potato production. At the same time, according to the Coelli's test, $H_0: \gamma = 0$, gives the value of gamma is 0.0000098 and it's p-value = 0.9995697 indicates highly insignificant and all of the deviations arises due to statistical stochastic noise or random shocks and there is no inefficiency due to climates and hydrology. It will also mean that there is no opportunity to increase Potato production in the Bangladesh by increasing technology and the country achieve maximum productions due to climates. Again, from the likelihood ratio test, the $\Pr(|\chi^2_{(1)}| \geq 0)$ = 0.4995, which implies to accept the null hypothesis that there is no production inefficiency of potato production due to climates and hydrology in Banglaedsh.

8.4. Measuring Efficiency of Vegetable Production

The parameter estimates of the Cobb-Douglas Stochastic Frontier model of vegetable production is given in the Table 4

Table 4: Summary Statistics of Vegetable Production Model

Coefficients	Estimate	Std. Error	z value	Pr(>|z|)
(Intercept)	-29.75612	1.86937	-15.9178	<0.00001
sun.sum	-0.74931	0.44165	-1.6966	0.089767
sun.dry	-0.88915	0.34706	-2.5619	0.010409
clo.sum	0.22399	0.59054	0.3793	0.704463
clo.dry	-0.18608	0.17243	-1.0791	0.280537
max.tem.dry	1.38545	1.21221	1.1429	0.253073
max.tem.sum	8.51564	1.64815	5.1668	<0.00001
min.tem.dry	-0.46535	0.85887	-0.5418	0.587943
min.tem.sum	-1.52129	1.4463	-1.0519	0.292867
rain.dry	0.08266	0.03833	2.1566	0.031033
rain.sum	0.07985	0.13618	0.5863	0.557666
rh.dry	-0.87442	0.82347	-1.0619	0.288291
rh.sum	3.40344	1.20933	2.8143	0.004888
wind.dry	-0.22424	0.19577	-1.1454	0.252029
wind.sum	-0.74336	0.20596	-3.6093	0.000307
sigmaSq	0.00414	0.00103	4.033	0.000055
gamma	0.00005	0.03242	0.0014	0.9988802

From the Table 4, it is clear that sun.sum, sun.dry, max.tem.sum, rain.dry, rh.sum and wind.sum have statistically significant effects on frontier vegetable production due to Climates and hydrology covering the whole county Bangladesh at 8% level of significance.

From the fitted model, Average Technical Efficiency is 0.9996537. The highest value of the efficiency is 0.9996559 which occurred in the year 2005 and the lowest is 0.9996516 which occurred in the year 1991. These result indicate all of the year are relatively well in achieving maximum vegetable production in Bangladesh due to climate. Efficiency rate approximately 100% gives the sense that all of the year achieve maximum vegetable production. At the same time, according to the Coelli's test $H_0: \gamma = 0$, which gives the value of gamma is 0.00005 and it's p-value for testing the hypothesis is 0.99888, indicates highly insignificant and all of the deviations arises due to stochastic noise and there is no technical inefficiency. Again, from the likelihood ratio test, the $\Pr(|\chi^2_{(1)}| \geq 0) = 0.4995$, which implies to accept the null hypothesis that there is no production inefficiency of vegetable production due to climates and hydrology in Banglaedsh.

8.5. Measuring Efficiency of Cereal Production

The parameter estimates of the Cobb-Douglas Stochastic Frontier model of cereal production is given in the Table 5

Table 5: Summary Statistics of Cereals Production Model

Coefficients	Estimate	Std.Error	z value	Pr(>|z|)
(Intercept)	68.000793	1.825863	37.2431	<0.0001
sun.sum	-9.974942	1.017791	-9.8006	<0.0001
sun.dry	-2.071771	0.896349	-2.3113	0.02081
clo.sum	-8.51905	1.567264	-5.4356	<0.0001
clo.dry	0.743378	0.592792	1.254	0.209831
max.tem.dry	19.717575	1.194469	16.5074	<0.0001
max.tem.sum	-25.356074	4.467341	-5.6759	<0.0001
min.tem.dry	-10.463184	2.352417	-4.4478	<0.0001
min.tem.sum	17.021244	3.012673	5.6499	<0.0001
rain.dry	-0.054219	0.154349	-0.3513	0.72538
rain.sum	-0.253073	0.596632	-0.4242	0.67144
rh.dry	0.179726	2.970116	0.0605	0.95175
rh.sum	-6.138028	3.127547	-1.9626	0.04969
wind.dry	0.268619	0.825516	0.3254	0.74488
wind.sum	-2.305507	0.884455	-2.6067	0.00914
sigmaSq	0.092216	0.110598	0.8338	0.404398
gamma	0.01214	1.829003	0.0066	0.994704

From the Table 5, it is clear that sun.sum, sun.dry, clo.sum, max.tem.sum, max.tem.dry, min.tem.dry, min.tem.sum, rh.dry and wind.sum have statistically significant effects on frontier cereal production due to Climates and hydrology at 5% level of significance.

From the fitted Stochastic Frontier Model of cereal production, Average Technical Efficiency is 0.97385. The highest value of the efficiency is 0.9761726, which occurred in the year 1985 and the lowest is 0.9712354, which occurred in the year 1978. These result indicate all of the year are relatively well in achieving maximum cereal production in Bangladesh due to climates and hydrology. Efficiency rate approximately 97% gives sense that all of the year almost achieve maximum cereal production. At the same time, according to the Coelli's test $H_0\colon \gamma = 0$, gives the value of gamma is 0.01214 and it's p-value = 0.9947 indicates highly insignificance and all of the deviations arises due to stochastic noise and random shocks. Again, from the likelihood ratio test, the Pr($|\chi^2_{(1)}| \geq 0$) = 0.4982, which implies to accept the null hypothesis that there is no production inefficiency of cereal production due to climates and hydrology in Banglaedsh.

8.6. Measuring Efficiency of Species production

The parameter estimates of the Cobb-Douglas Stochastic Frontier model of species production is given in the Table 6

Table-6: Summary statistics of Species production Model

Coefficients	**Estimate**	**Std.Error**	**z value**	**Pr(>|z|)**
(Intercept)	-63.2087	2.97043	-21.2793	<0.0001
sun.sum	4.44748	0.82618	5.3832	<0.0001
sun.dry	-2.49992	0.70305	-3.5558	0.00038
clo.sum	5.56999	0.96173	5.7917	<0.0001
clo.dry	-1.0204	0.37051	-2.7541	0.00589
max.tem.dry	-3.43957	1.04399	-3.2946	0.00099
max.tem.sum	19.59762	1.17723	16.6472	<0.0001
min.tem.dry	2.95675	1.35904	2.1756	0.02958
min.tem.sum	-2.00213	1.29114	-1.5507	0.12098
rain.dry	0.00491	0.09047	0.0542	0.95675
rain.sum	0.41855	0.34169	1.2249	0.22060
rh.dry	-1.82408	1.29035	-1.4136	0.15747
rh.sum	1.30727	0.99721	1.3109	0.18989
wind.dry	0.281	0.48722	0.5767	0.56412
wind.sum	-0.65254	0.50114	-1.3021	0.1928747
sigmaSq	0.031	0.00762	4.0673	0.0000476
gamma	0.00001	0.01487	0.0006	0.9995159

From the Table 6, it is clear that sun.sum, sun.dry, clo.sum,col.dry, max.tem.sum, max.tem.dry and min.tem.dry have statistically significant effects on frontier species production due to Climate at 5% level of significance.
From the fitted Stochastic Frontier model of species production, Average Technical Efficiency is 0.99958. The highest value of the efficiency is 0.9995802, which occurred in the year 2005 and the lowest is 0.9995772, which occurred in the year 1998 and 2001. These result indicate that all of the year are relatively well in achieving maximum species production in Bangladesh due to climates and hydrology. Efficiency rate approximately 100% gives sense that all of the year achieve maximum species production. At the same time, according to the Coelli's test $H_0\colon \gamma = 0$, gives the value of gamma is 0.00001 and it's p-value for testing the hypothesis is 0.99952, which indicates highly insignificant and all of the deviations are arisen due to stochastic noise and there is no technical inefficiency. It will also mean that there is no opportunity to increase species production in the Bangladesh by increasing technology and the country achieve maximum productions due to climates and hydrology. Again, from the likelihood ratio test, the Pr($|\chi^2_{(1)}| \geq 0$) = 0.4996, which implies to accept the null hypothesis that there is no production inefficiency of species production due to climates and hydrology in Banglaedsh.

9.Conclusion and Recommendations

In this study, it is tried to fit a Cobb-Douglas production frontier function to measure production efficiency of different types of agricultural production due to climates and hydrology in Bangladesh from 1972 to 2006. To serve this purpose, Climatic and hydrological information is divided into two season named as dry season which covers the months October, November, December, January and February, and summer season which covers the months March, April, May, June, July, August and September considering the climatic condition of Bangladesh. From this is analysis, it is found that Average Technical Efficiency for rice productions is 0.9203. The highest value of the efficiency is 0.99727 which occurs in the year 2000 and the lowest is 0.72164 which occurs in the year 1972. Average Technical Efficiency for cereal productions is 0.97385. The highest value of the efficiency is 0.9761726 which occurs in the year 1985 and the lowest is 0.9712354 which occurs in the year 1978. There is a little chance to achieve maximum productions by increasing Technology. At the same time, Average Technical Efficiency for vegetables, jute, potato and species productions are 0.9996537, 0.9963437, 0.9996387 and

0.99958 respectively, which are shown that they achieve maximum production due to climates and hydrology. Policy makers, producer can use this analysis to make a decision and climatic conditions similar to Bangladesh also can do it.

From the study, it is found that Maximum Temperature of the Summer Season and Minimum Temperature of the Summer Season have statistically significant effects on frontier rice production. Similarly, Sunshine of the Summer Season, Maximum Temperature of the Dry Season, Maximum Temperature of the Summer Season, Minimum Temperature of the Dry Season and Minimum Temperature of the Summer Season have statistically significant effects on frontier Jute production. At the same time, Cloud Coverage of the Dry Season, Maximum Temperature of the Dry Season, Minimum Temperature of the Dry Season and Minimum Temperature of the Summer Season, Amount Rainfall of the Summer Season, Relative Humidity of the Summer Season and Amount Rainfall of the Summer Season have statistically significant effects on frontier Potato production. Moreover, Sunshine of the Summer Season, Sunshine of the Dry Season, Maximum Temperature of the Summer Season, Amount Rainfall of the Summer Season, Relative Humidity of the Summer Season and Wind Speed of The Summer Season have statistically significant effects on frontier vegetable production. Again, Sunshine of the Summer Season, Sunshine of the Dry Season, Cloud Coverage of the Summer Season, Maximum Temperature of the Dry Season, Maximum Temperature of the Summer Season, Minimum Temperature of the Dry Season, Minimum Temperature of the Summer Season, Relative Humidity of the Dry Season and Wind Speed of The Summer Season have statistically significant effects on frontier cereal production. Furthermore, Sunshine of the Summer Season, Sunshine of the Dry Season , Cloud Coverage of the Summer Season, Cloud Coverage of the Dry Season, Maximum Temperature of the Dry Season, Maximum Temperature of the Summer Season and Minimum Temperature of the Dry Season have statistically significant effects on frontier species production.

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