Bio- Economic Modelling of Climate Change on Crop Production in India

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1.Introduction:

Climate is one of the main determinants of agricultural production Through out the world there is significant concern about the effects of climate change and its variability on agricultural production. Researchers and administrators are concerned with the potential damages and benefits that may arise in future from climate change impacts on agriculture, since these will affect domestic and international policies, trading pattern, resource use, and food security. The researchers are of the opinion that while crops would respond favorably to elevated CO_2 in the absence of climate change, the associated impacts of high temperatures, changed pattern of precipitation and possibly increased frequency of extreme events such as drought and floods, would possibly combine to reduce yields and increase risks in agricultural production in several parts of the globe. In India agricultural production is often determined by the whims of nature. The climate change is expected to result in higher temperatures and rainfall. The higher expected temperature might lower the yields. However, at the same time, higher rainfall could enhance growing period of crops. Also the higher concentration of CO_2 in the atmosphere under changed climatic conditions might act as aerial fertilizer and enhance crop yields. All these factors have to be taken in to consideration while examining the climate change impact on agriculture.

During the 1990s, researchers repeatedly claimed that global warming would have dire consequences for key crops. Professor Richer Adams, an agricultural economist says, “If

you just take an agronomic model and make conditions hotter and drier, then, yes, crop yields go down." " But if you are a farmer, you see your crops aren't doing so well and plant a more resistant type.

In India, climate change is expected to make an impact in agriculture, resulting in lower yields of crops. The objectives of this paper are to examine the effect of fertilizer and labor inputs on crop productivity and to investigate the impact of climatic variables such as rainfall and temperature on crop production.

Climate response functions have been estimated, using regression model by incorporating weather variables, in order to examine the impact of climate change on productivity of two crops. The impact of weather variables has been examined and the study is confined to two states.

2. Methodology

In a study Kaufmann R. K. and Seth E Snell (1997) had specified yield as a linear function of purchased inputs. For the purpose of analysis seed, fertilizer and labor inputs were considered in the regression model as explanatory variables and yield as the dependent variable. However, crop yield is affected not only by these purchased inputs but also by climatic variables and social factors. This integration allows complementing the earlier methodologies, which concentrate only on the purchased inputs and thereby, allows to better evaluating the adaptation strategy to climate change. The results show that climatic variables account for 19% of the yield change while the social variables account for 74% of the yield change.

Kavi Kumar and Parikh (2001) has also established a functional relationship between farm level net revenue and climatic variables, with a view to estimate the climate sensitivity of crop production in Indian agriculture.

To assess the impact of climate related variables and agricultural production in India, the present study has been undertaken. For this purpose, two crops viz. Rice and Jowar have been selected. These two crops are predominantly grown in monsoon season and any change in climate, particularly rainfall and temperature would effect the productivity of these crops significantly. In the present paper an econometric bio-model of crop production has been attempted. Agricultural production depends on not only climate related variables, but also on use of several factors like fertilizer, labour and other resources. For the purpose of present study, the following model has been used:

Y= f (F, HL, AR, NR, DFNR, MAXTEMP, MINTEMP)

Where,

Y= Crop yield on per hectare basis

F = Fertilizer used/ ha.

HL = Human labour in hours/ha.

AR = Actual Rainfall (mm)

NR = Normal Rainfall (mm)

DFNR = Deviation from normal rainfall(mm. or %)

MAXTEMP = Mean maximum temperature during crop season (^{0}C)

MINTEMP = Mean minimum temperature during crop season (^{0}C)

The model was estimated for Rice and Jowar crops. The analysis was undertaken for the country as a whole, using state wise data for both these crops. The study was also undertaken using district wise data as well. For Rice crop, the state of Orissa has been selected, because thisis the main crop of the state. For Jowar, the state of Karnataka has been selected, because of it's significance in the region. Data on different variables for various states has been collected from the publications of Directorate of Economics and Statistics, Ministry of Agriculture, as well as from the Economics and Statistics Directorates of various states. Similarly district-wise data has been primarily collected from the publications of these two state govts.

Least square technique has been used to estimate different regression equations for the country as a whole as well as for both the states. Several forms of equations were analyzed and results were computed. The analysiswas done under usual assumptions. It has been hypothesized that productivity of the selected crops is positively influenced by the application of chemical fertilizers and human labour . These two are the main purchased inputs in the production of these crops. Climate, in the present model, has been approximated by rainfall – actual, normal as well as deviation from the normal.Other variables representing the climatic factors are mean maximum and mean minimum temperature in crop growing period .This has been further hypothesized that extreme variations in these variables such as excessive rain or scanty rain and very high or low temperature would adversely affect the crop productivity in the selected states and districts for the selected crops.

3. Results and Discussion

In order to study the impact of climate change on productivity, regression equations were estimated using the model and data stipulated in the methodology. As already mentioned, earlier various forms of functions were estimated and out of these, linear form provided the best fit and therefore, only linear regression equations have been presented for Rice and Jowar crops for the country as well as both the selected states. Table 1 presents regression equations for rice productivity and climate, using state-wise data for the country as a whole .Variable pertaining to fertilizer use, human labour, actual rainfall and temperature pertains to year 2000-01, whereas normal temperature consists of observations from a period of 30 years.

Table 1; Estimated Regression Equations for Rice Productivity and Climate

-State-wise Analysis

Intercept	Use of Fertilizer (Kg./ha.)	Human Labour (Hours./ha.)	Actual Rainfall	Deviation from Normal Rainfall (%00)	Mean Max. Temp.	Mean Mini. Temp.	R^2
1222.381 (1440.894)	14.992** (3.329)	0.122 (0.910)	-3.063 (3.615)		-35.536 (38.957)	58.253 (32.839)	73
1296.367 (1283.654)	15.162** (2.968)	-	-2.917 (3.324)	-	--36.563 (36.833)	60.703** 926.316)	73
473.001 (2199.274)	-	-	-	-16.634 (25.537)	20.658(59.120)	38.622 (50.892)	13
1436 (1263.894)	15.944** (2.810)	-	-	-	46.464 (34.793)	52.544* (24.429)	72
1687.794 (218.081)	-	-	-	-25.824 (20.472)	-	-	9

A perusal of results indicate that the variables of fertilizer used, human labour, actual rainfall, mean maximum temperature and mean minimum temperature, explained 73% of

variation in the productivity of Rice. This implies that productivity of Rice on per hectare basis is influenced by these variables. Moreover, the fertilizer use variable had a highly significant co-efficient, suggesting a significant impact of fertilizer use on productivity. Surprisingly, the variables pertaining to actual rainfall and maximum temperature, during the growing period of the crop, had negative coefficient, implying that these two variables had negative impact on productivity. The mean minimum temperature had a statistically significant and positive coefficient, implying that this variable would effect the productivity of Rice positively.

Estimated regression equations for Rice crop and climate related variables, using data from various districts of Orissa state are given in Table 2. Similar to the earlier analysis, results pertaining to the linear regression have been presented.

Table 2; Estimated Regression Equations for Rice Productivity and Climate

-District -wise Analysis (Orrisa)

Intercept	Use of Fertilizer (Kg./ha.)	Normal Rainfall (mm.)	Actual Rainfall	Deviation from Normal Rainfall (%00)	Mean Max. Temp.	Mean Mini. Temp.	R^2
1099.97 9895.824)	6.333 (5.298)	-	0.404 (0.903)	-	-	-	6
-3272.018 (2574.242)	9.657 (5.845)	1.606 (1.319)	-	-	68.48794 5.942)	-5.439 (40.322)	28
-452.369 (2119.097)	7.059 (5.083)	1.290 (1.402)	-	-	-	-	9
2082.823 (2156.601)	6.950 (5.854)	-	0.334 (0.943)	-	-28.756 (49.669)	2.749 (46.173)	7
2366.532 (1917.531)	7.689 (5.954)	-	-	-0.315 (1.071)	-34.592 (50.906)	5.866946 .379)	7

The results indicate that the variable of fertilizer use, normal rainfall, minimum and maximum temperature could explain 28% of variation in Rice yield. When actual rainfall variable was replaced by the deviation in the rainfall from the normal, the value of R^2

dropped down to 7 percent , implying that the actual rainfall had better explanatory power, than that of deviation in rainfall from normal. Results also indicated that mean maximum and minimum temperature could explain a larger part of variation in the Rice yield. Maximum temperature had a negative coefficient. It has implication that the increasing temperature would effect the productivity of Rice negatively, in the state.

The state-wise analysis for Jowar productivity and climate related variables are presented in Table 3.

Table 3; Estimated Regression Equations for Jowar Productivity and Climate

-State-wise Analysis

Intercept	Use of Fertilizer (Kg./ha.)	Human Labour (Hours./ha.)	Actual Rainfall	Deviation from Normal Rainfall (%00)	Mean Max. Temp.	Mean Mini. Temp.	R^2
48.800 (671.896)	-0.395 (1.241)	3.460* (1.344)	-0.437 (1.251)	-	21.61 (13.688)	6.960 (9.591)	52
47.030 (677.786)	-0.359 (1.238)	3.501* (1.349)	-	-1.419 (5.733)	-22.296 (13.446)	4.143 (10.887)	52
44.194 (669.416)	-0.500 (1.208)	3.359* (1.319)	-	-2.615 (5.360)	-19.237 (12.648)	1.283 (10.006)	49
-633.126 (483.595)	-1.030 (1.168)	3.410** (1.327)	-	-3.886 (4.585)	-	-	40
176.963 (569.985)	-	3.061** (1.071)	-	-2.673 (5.197)-	-20.742 (11.750)	1.250 (9.705)	48

The results indicated that the use of fertilizer variable has a negative impact on Jowar productivity, which is not correct on theoretical grounds. However, the human labour variable has a positive and statistically significant impact on Jowar productivity. The deviation from normal rainfall had negative impact on productivity. This implies that rainfall contributes significantly in raising productivity of Jowar, which is normally a rainfed crop. The mean maximum temperature, during the growing season of the crop had a negative implication for the crop, while the minimum temperature, during the same

period, would effect the crop productivity positively. The R^2 in all five selected equations are good and it's value ranges between 40% to 52%.

Estimated regression equations for Jowar productivity in the state of Karnataka are presented in Table 4. District-wise data has been analyzed. A perusal of the results indicate that use of fertilizer has negative impact on the crop productivity, which is theoretically inconsistent.

Table 4; Estimated Regression Equations for Jowar Productivity and Climate -District -wise Analysis (Karnataka)

Intercept	Use of Fertilizer (Kg./ha.)	Normal Rainfall (mm.)	Actual Rainfall	Deviation from Normal Rainfall (%00)	Mean Max. Temp.	Mean Mini. Temp.	R^2
1523.768 (995.551)	-0.674 (1.243)	-0.154 (0.107)			9.018 (40.494)	47.264 (65.742)	12
981.465 (213.603)	-0.847 (1.176)	-0.150 (0.103)			-	-	9
1122.249 (977.071)	-0.473 (1.262)	-			17.429 (40.978)	-49.968 (67.207)	4
903.631 (923.053)	-0.676 (1.220)	-			-3.478 (29.527)	-	1
1523.770 (995.55)	-0.674 (1.242)	-	-0.154 (0.108)	-	9.018 (40.494)	-47.264 (65.742)	12

The rainfall during the crop growth period has also negative coefficient. Whereas mean maximum temperature will effect the crop positively. The results indicate that the effect of climate related variables have mixed effects on productivity of Jowar, as rainfall shows negative impact, while maximum temperature has a positive effect. However,for understanding the real effect of these variables on productivity of Jowar crop, a detailed study is required.

4.Conclusions

Climate plays an important role in shaping agricultural production in India. Lack of irrigation makes agriculture a gamble with nature. The effects of climatic variability is quite visible in case of majority of farmers who are marginal and small and lack resources required for adjustment for climatic variations. The present study covers rice and jowar crops for the country as a whole as well as for the states of Orissa ang Karnataka.

The study reveals that excessive rains and extreme variation in temperature would affect the productivity of these crops adversely thereby affecting the incomes of farming families in a negative manner. Thus suitable strategies pertaining to resource use, planting flood and drought resistant varieties of crops, better irrigation networks , and crop mix are to be adopted for mitigating the harmful effects of climatic changes.

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