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Economic Impact of Climate Change on Agriculture Sector of Coastal Odisha

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Abstract

The present study tries to explore the economic impact of climate change on agriculture of the coastal zone of Odisha using Ricardian approach. The climate response function of the farm level net revenue has been estimated through pooled cross-section and time series regression analysis. The results reveal that most of the climate variables and control variables have significant influence on the net revenue per hectare of the region. Using the estimated trends of the various seasons over 30 years, it is found that the rising temperature might adversely affect the coastal zone's agriculture of Odisha.

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Keywords: Economic impact; Climate change; Ricardian Approach; Coastal zone of Odisha; India.

1. Introduction

The sensitivity of agriculture to climate change has become a dominant area of research in the present day era. Climate change in Intergovernmental Panel on Climate Change (IPCC) usage refers to a change in the state of the climate that can be identified (e.g. using statistical tests) by changes in the mean and/or the variability of its properties and that persists for an extended period, typically decades or longer. It is likely to have both positive and negative impact on agriculture [1] depending on the physiological characteristic of the region and the crops being produced. Scientists who are engaged in projections of changing climatic impact predict that rising temperatures will have a significant impact upon crop yields, most noticeably on the

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poorest countries that are in the tropics and sub-tropics by 2100 [2]. In this connection, India which is located in the south and comes under tropical zone is more vulnerable to climate change because it is an agrarian and developing economy.

The present study is an attempt to examine the economic impact of climate change on agriculture of the coastal zone of the state which comprises nine districts (comes under two agro-climatic zones of Odisha: north eastern coastal plain and south eastern coastal plain). Odisha is one of the coastal states of India which has the highest proportion of poor persons in its population, among all the Indian States and Union Territories. About 80-85 percent of state's population are living in rural areas. The state is primarily an agrarian economy because the sector provides employment to more than 70% of total workforce directly or indirectly, making it the largest employment sector of the state. According to the 64th round of National Sample Survey Organisation (NSSO), the monthly per capita consumer expenditure (MPCE) for rural and urban Odisha is below the respective national averages. The Engel's ratio(which measures the share of food expenditure in total expenditure and has been widely used as a measure of standard of living) for Odisha is higher than the all India level both in rural and urban areas. According to the latest India Human Development Report, the ranking of Odisha is the second lowest among all the Indian states for a period 1990-91 to 2007-08. The share of agriculture sector in NSDP is higher than that of the industrial sector in Odisha unlike at the all India level. But the share of agriculture in NSDP shows a declining trend over the years that is 29.7 (2000-01 to 2004-05), 22.4 (2005-06 to 2009-10), 21.1(2009-10), 20.6 in 2010-11 [3]. As such, it is imperative to achieve higher growth of agriculture on a sustainable manner to uplift the society from underdevelopment and poverty.

Coming to the status of climate of the state, the state is coming under tropical zone and is characterized by high temperature, high humidity, medium to high rainfall and short and mild winters. The dependency syndrome of agriculture on rainfall status is very high in the state and climatology has direct bearing on the distorted growth rates of social and economic sectors of Odisha since long [4]. On this backdrop, it is very important to assess the climate sensitivity of agriculture of Odisha. The coastal zone has been chosen for the present study because the exploitation of cultivable land is comparatively more in this region in the state and the major portion of food grain production of the state comes from this coastal zone. From the population point of view, coastal Odisha has higher density of population i.e. 14.5 percent of area inhabits nearly 30% of total population. Therefore, even a nominal persistent decrease in food production may lead to adverse consequences.

Over the years, numbers of studies have been carried out to explore the economic impact of climate change on agriculture. The models used for the economic impact assessment can be classified into two major types, namely the economy-wide (general equilibrium) and partial equilibrium models. Economy-wide models are the general equilibrium models that take the economy as a complete system of interdependent components. On the other hand, Partial equilibrium models, are based on the analysis of part of the overall economy such as a single market (single commodity) or subsets of markets or sectors [5-6]. Because of the sophistication involved in its use, economy wide models are generally unsuitable for developing countries like India. Hence, partial equilibrium models are normally used in those countries. The partial equilibrium models available in the literature can be classified into crop suitability approach, agronomic-economic approach and Ricardian approach. The crop suitability approach otherwise known as the agro-ecological zoning approach uses a simulation of crop yields to assess the suitability of various lands and biophysical attributes for crop production. The agronomic economic approach is based on controlled experiments in field or laboratory settings. But both these approaches failed to take adaptations into account. Since, various adaptation possibilities are available for farmers, the study which takes care of private adaptations would rather give a better outcome. Whereas the first two approaches use simulation technique and controlled experimentation respectively, the last one or the Ricardian approach is a cross section based analysis that takes adaptation into account. It was Mendelsohn et al (1994) [7], who developed the Ricardian approach to climate change impact study on US agriculture, by using economic data on the value of land. Instead of studying yields of specific crops, the method examines how climate in different places affects the net rent or value of farm land. By directly estimating the net farm revenues, the method account for the direct impacts of climate on yields of different crops as well as the indirect substitution of different inputs and other potential adaptation to different climates (which gets reflected in costs). Besides being applied to developed countries the method has also been used recently in the developing countries to measure the economic impact of climate change on the agriculture sector [8-11]. In case of India, Kumar and Parikh (2001) [12] have tried to measure the climate sensitivity of Indian agriculture by adopting the Ricardian approach. Though the approach was first used in US taking the land values into consideration, in case of developing countries farm level net revenue is being used because of absence of organized land market. However, the outcomes of all these studies imply that climate change would be slightly beneficial to US agriculture, but it is likely to be harmful to tropical and semi tropical countries.

2. Methodology

In the present study the Ricardian approach has been used to measure how climate change affects net revenue (per hectare) of the coastal zone of Odisha (for all the nine coastal districts). We have estimated a functional relationship between farm level net-revenue and climate variables (temperature and rainfall) using pooled cross sectional and time series regression, while controlling for various geographic and economic variables. Secondly, the estimated trend of the 30 years average climate for the region is used to examine the impact of climate change on agriculture of the region. The dependent variable and the control variables used in the study except soil, are district level annual data from 1993-2009 for the nine coastal districts, whereas the independent seasonal climate variables are the averages over 30 year climate (which is considered as normal climate for the region). All prices and wages used in the study have been deflated using the agricultural GDP deflator (1993-2009).

For this monthly temperature and rainfall data for over 30 years (1979-2009) has been collected from Indian Meteorological Department for the coastal zone. Annual district level agricultural data (input and output) and data on other control variables has been collected from various issues of the district statistical handbooks and from the department of Agriculture and Statistics, Government of Odisha.

There are various ways one could represent the monthly climate data. For this study, three months average seasons have been taken. Thus, the average of January, February and March is represented as January, April, May and June is represented as April, July, August and September is represented as July, October, November and December is represented as October. The functional relationship of the net revenue climate response function is represented as below:

$$R = \beta_0 + \beta_1 T_S + \beta_2 T_S{}^2 + \beta_3 P_S + \beta_4 P_S{}^2 + \beta_5 T_S P_S + \beta_6 PD + \beta_7 ALTR + \beta_8 CLT + \beta_9 BLCK + \beta_{10} TRCTR + \beta_{11} PHYV + \beta_{12} PIRGN + \varepsilon$$

Where, R is the district level net revenue per hectare, Ts and Ps are the normal temperature and precipitation respectively, s represents season. *PD* and *ALTR* are the population density and adult literacy rate respectively. *CLT*, *BLCK*, *TRCTR* are the number of cultivators (which accounts for household labour), bullocks and tractors per hectare respectively. *PHYV* and *PIRGN* are proportion of area under high yielding varieties seeds and proportion of area under irrigation respectively. ε denotes the error term. The dependent variable in the study i.e. district level net revenue (R) is the difference of the value of crops produced and the expenditure on inputs (fertilizer, agricultural labourer and seeds) weighted by the total area under crops. For estimating the net revenue 13 major crops of the state has been taken. They are: paddy, wheat, maize, ragi, greengram, blackgram, horsegram, til, groundnut, mustard, potato, jute and sugarcane. Since, the soil of the coastal zone is deltaic alluvial (for almost all the nine districts), we have dropped the variable from the list.

The quadratic term is used in the above equation to capture the non-linear relation of the net revenue climate response function. Based on literature on agronomic studies it is expected that when the quadratic function is positive, the net revenue function is U-shaped and when the quadratic term is negative, the function is hill-shaped. However, the study of seasonal climate variables may result in a mixture of positive and negative coefficients across seasons [11].

3. Results and Discussion

The agricultural crop year in Odisha is from July to June. The cropping season is classified into two main seasons: *Kharif* season and *Rabi* season. The *Kharif* cropping season is from July-October during the south-west monsoon. In the *Kharif* season the planting, growing and harvesting stages occur in April, July and October respectively. The *Rabi* season starts with the onset of north-east monsoon in October. The planting, growing and harvesting stages in *Rabi* season occur in October, January and April respectively [12]. The *Kharif* crops include paddy, maize, ragi, groundnut (oilseeds), etc. The *Rabi* crops include wheat, greengram, blackgram, horsegram, mustard, etc. The estimated results of the pooled regression analysis for the climate coefficients and the control variables have been shown in the following table.

Table 1. Regression coefficients explaining farm level net revenue

Variable	Coefficient	Variable	Coefficient
January temperature	-26.42	October rainfall	-0.15
January temperature square	3.67**	October rainfall square	-0.002*
April temperature	-23.23*	January temperature x January rainfall	0.173
April temperature square	-2.20*	April temperature x April rainfall	-0.01
July temperature	837.104**	July temperature x July rainfall	-0.05*
July temperature square	-14.37***	October temperature x October rainfall	0.04
October temperature	382.22*	Population density	0.22*
October temperature square	-16.87***	Adult literacy rate	-4.09**
January rainfall	3.65*	Cultivators per hectare	38.89*
January rainfall square	-0.01	Tractors per hectare	512.96***
April rainfall	3.47*	Bullocks per hectare	-15.02
April rainfall square	0.002*	Proportion of area under HYV	3.11*
July rainfall	0.82*	Proportion of area under irrigation	32.55*
July rainfall square	-0.001***		
Constant	-1302.43**		
Prob>chi 2	0.0000		

*Note: * denotes 10% level of significance, ** denote 5% level of significance and *** denote 1% level of significance.*

The findings of the study reveal that rainfall of seasons January and April have positive effect on the net revenue. This is because January rain is beneficial for the *Rabi* crops which are generally heat sensitive and requires soil moisture for their growth. April rain helps in seeding process of the *Kharif* crop and also helps the seeds in their germination. But rise in temperature in this period is harmful because it reduces the soils moisture retaining capacity. Thus, temperature rise in April has a negative effect on the net revenue. During July monsoon rain helps the *Kharif* crops to grow. Both July rainfall and July temperature have positive effect on net revenue. This may be because both temperature and rainfall are needed at this time for the *Kharif* crops to grow. October season which is the harvesting period for *Kharif* crops and planting period for *Rabi* crops requires less water. This could be a possible reason behind the negative coefficient for the season October rainfall. During this time temperature has a positive effect on net revenue. This result might have come for the possible reason that temperature rise during this period helps the *Rabi* crops like blackgram, greengram, etc from the insect attacks and also helps the *Kharif* crops in the ripening process. Among the control variables population density, number of cultivators per hectare, number of tractors per hectare, proportion of area under irrigation are positively and significantly influence farm revenue per hectare. Adult literacy rate shares a negative relationship with farm level net revenue because with increased education people prefer more non-agricultural activities to farming. Finally, we relate the estimated 30 years average trend of climate variables with this result. The trend for January rainfall is estimated to be negative (-0.31) and the trend for July rainfall is revealed to be positive (2.02). The results for other two seasons (for rainfall) do not have a significant trend. On the otherhand, the trend of temperature for all the seasons are showing increasing trend.

4. Conclusion

To conclude, the estimated regression coefficients of rainfall of January, April and july have positively influenced the net revenue. It is also found from the study that the coefficients of the January temperature and April temperature are negative whereas July temperature and October temperature share positive relation with net revenue. The relation between the estimated 30 years trend of the seasonal climate variables and the coefficients of regression analysis reveals that the negative trend of January rainfall for the region might adversely affect farm level net revenue, which calls for a greater investment in irrigation in this period. July rainfall is beneficial to farming activity in Odisha. On the otherhand, the increasing trends of temperature for all the seasons might have adverse impact on the health of agriculture sector of coastal Odisha.

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