Ricardian Land Valuation Theory: Spatial and Temporal Investigation in Pakistan

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Abstract

Unequivocal phenomenon of climate change has caused significant impacts on water and energy resources, agriculture sector and consequently human livelihood particularly in developing countries. This study is a pioneer attempt to quantify quasi-dynamic trends and impacts of climate change on Pakistani farms by using interpolated climate data and incorporating spatial autocorrelation in Ricardian analysis. Ricardian estimates found that climate change has significantly decreased farm revenues in Pakistan over time. Significant losses in 2010-11 were found to be more in comparison to 1998-99. Likewise, more elastic farm revenues in 2010-11 confirmed the growing negative impacts of climate change on farm revenues. Threshold levels for mean temperature and minimum temperature are already met since further increase in mean(minimum) temperature will decrease(increase) farm revenues in Pakistan. The study suggested mix cropping system instead of crop only farming, use of climate resilient seeds and introduction and implementation of cooperative farming that may prove a good step towards betterment of Pakistani farmers in changing climate settings.

Keywords: Climate change; Pakistan agriculture; Ricardian analysis; spatial analysis; interpolation; land valuation theory

Introduction

Asia, the world's most populous continent having 63 percent of the world population, is extremely sensitive to global warming. Per unit yield of various crops in Asia is projected to decrease under diversified scenarios causing increasing risk of livelihood, food insecurity and hunger to climate variability. It's most vulnerable regions to increasing climate events are the Northern South Asia, West Japan, East China and south part of Indochina Peninsula (IPCC, 2014). Among South Asian countries, Pakistan is the frontline state confronting serious concerns of climate change (IUCN, 2009). The country is ranked at 3rd most vulnerable region to climate change after Haiti and Philippines (GCRI, 2014) regardless of the fact that its contribution in atmospheric concentration of GHGs is merely 0.8 percent of global GHGs emission

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(PMD, 2009). Negative impacts of climate change on agriculture have directly influenced livelihood of rural population due to heavy reliance on natural resources on one hand and may cause food inflation and increase cost of living on the other. Consequently, rural poverty is likely to exacerbate particularly in Pakistan.

Following Ricardo's theory of land rent (Ricardo, 1809), Mendelsohn *et al.* (1994) developed a theory named "Ricardian land valuation theory" which relates land values or Net Farm Revenues (NFR) to climate factors spatially. Ricardian analysis was initiated by Mendelsohn *et al.* (1994) in US context. Following Mendelsohn *et al.* (1994), a large number of Ricardian studies have been conducted worldwide including USA, European countries, African and Asian countries to estimate the impact of climate change on agriculture. Cline (1996) and Kelly *et al.* (2005) criticized Ricardian approach due to ignoring transition cost and price changes. Mendelsohn and Nordhaus (1996) claimed that this bias is very small if there are no substantial changes in aggregate supply. Furthermore, transition cost is a short run phenomena whereas Ricardian analysis assesses long term climate-agriculture sensitivity (Easterling, 1996; Sanghi and Mendelsohn, 2008).

In Pakistan's milieu, only a few research endeavors have been made to examine the impact of climate change on farm land values through Ricardian analysis. They showed adverse impacts of climate change on Pakistan's agriculture (Hanif, 2010; Shakoor *et al.*2011; Ahmed and Schmitz, 2011; Saboor, 2014). But there is hardly any study dealing with spatial correlation for aligning agriculture sector to earning situation. Furthermore, regional data limitations for climate variables are of major concerns that are unavailable due to operations of few metrological stations in the country. Using large data sets of Household Integrated Expenditure Survey (HIES), this study is first national level attempt for spatial investigation to check and compare climate variability impacts on Pakistan's agriculture across time by using combination of cross sectional and interpolated time series climate data sets.

Methodology

Ricardian land valuation theory (Mendelsohn *et al.,* 1994) states that changes in climate factors affect productivity of land hence land values so farmers switch from one crop to other to maximize farm revenues. Ricardian approach incorporates such farm level adaptations to climate change to give consistent estimates. Mathematical form of land value-climate function thus becomes (Mendelsohn *et al.,* 1994):

$$NFR = \beta_0 + \sum_{i=1}^{p} \beta_i CN_i + \sum_{i=1}^{q} \gamma_i NCV_i + \mu_i \tag{1}$$

The NFR per hectare in Ricardian approach are regressed on different Climate Normals (CN) and Non-Climate Variables (NCV). The study estimated climate normals by using equal weighted average of 30 years data of all climate variables. The data for 52 metrological stations could be acquired from Metrological Department of Pakistan that was inadequate for cross sectional Ricardian analysis of entire country. All estimated climate normals were then spatially interpolated across districts by using Inverse Distance Weighted (IDW) method.

The data for non-climate variables were obtained from Household Integrated Economic Survey (HIES) 1998-99 and 2010-11 from Federal Bureau of Statistics (FBS). Monetary variables of 2010-11 were adjusted to the base year of 1998-99 to eliminate the effect of inflation and to avoid misleading results. Deflating factor was calculated as:

$$Deflating\ Factor = \frac{100}{General\ Consumer\ Price\ Index} \quad (2)$$

Table 1: Estimation of deflating factor from CPI_G

Fiscal Year	CPI_G (Base 2000-01)	CPI_G (Base 1998-99)	Deflating Factor
1998-99	92.46	100	1
2010-11	244.26	264.18	0.38

Source: Pakistan Economic Survey 2013-14, Fiscal year 1998-99 was taken as base year.

The data for non-climate variables was arranged at district level through statistical averaging techniques. These farm level data sets are artfully stitched to climate normals for Ricardian regression. The study used quadratic functional form of models because of non-linear established relationship between land values and climate factors (Mendelsohn *et al.*, 1994).

Ricardian analysis may suffer from spatial autocorrelation because knowledge about farm management practices is diffused across boundaries due to social interaction among farmers (Kumar 2009). Likewise, climate variables across space are correlated that requires accounting for spatial autocorrelation in Ricardian regression to get unbiased estimates. Mathematical formation for spatial correlation models is:

$$NFR = \lambda W_Y + X\beta + \mu \qquad \text{SAR Model (3)}$$

$$NFR = X\beta + \mu$$
$$\mu = \rho W_\mu + \upsilon \qquad \text{SEM Model (4)}$$

Where SAR and SEM are Spatial Autoregressive Models and Spatial Error Models respectively. While X is the vector of climate and non-climate variables, β is vector of coefficients and W is spatial weight matrix in these models. The study used Rook based contiguity weight matrix of order 1 for districts while μ and υ are usual error terms.

Results and Discussions

Model estimation and selection

The study estimated classical regression, SAR and SEM models. Highly significant value of Moran's I providing the evidence of spatial autocorrelation in both models. Highly significant Lagrange LM statistics proposed the SAR models for both data sets (Table 2).

Table 2: Models' Diagnostics for spatial dependence

Models	Moran's I	Lagrange LM Statistics	
		SAR Model	SEM Model
Model 1 [1998-99]	3.2011 (0.0012)	6.2091 (0.0041)	3.6142 (0.0951)
Model 2 [2010-11]	3.7400 (0.0002)	9.4398 (0.0021)	2.3424 (0.1259)

Figures in parenthesis are estimated probabilities of LM statistics.

Table 3: Ricardian estimates from spatial autoregressive models

Factors	Ricardian Estimates	
	1998-99	2010-11
Mean Temperature	10497.85	31194.65**
Minimum Temperature	-5370.68	-16875.77**
Maximum Temperature	8749.37	18070.13
Total Precipitation	-33.75**	-70.18**
Mean Temperature Squared	-334.38	-916.88**
Minimum Temperature Squared	245.92	684.87**
Maximum Temperature Squared	-137.97	-242.60
Total Precipitation Squared	0.02***	0.04*
Share of Irrigated Land	6939.7***	-22.23
Literacy Ratio	4958.19	27477.68*
Share of Small Farmers	18281.07***	-782.95
Operational Land Holdings (Hectare)	-1503.31**	911.02
Quality Seeds	35947.40*	-73860.72
Share of Crop only Farming	-8212.74**	-7394.69*
Agriculture Services	14709.00	-13669.80
CONSTANT	-178704	-415249
Spatial Coefficient	0.42*	0.44*
R-Squared	0.63	0.53

*, **, *** represents level of significance at 1 percent, 5 percent and 10 percent respectively.

Marginal effects and elasticities from climate factors

Non-significant climatic variables except total rainfall in Model 1 is showing that climate change had not much effect on NFR in 1998-99 while all of the climate variables except maximum temperature in Model 2 are significant representing that climate change has significant impact on NFR in 2010-11. Climate coefficients of quadratic Ricardian regressions do not give marginal effects (Table 3) so marginal effects are calculated from Ricardian coefficients (Table 4). The results showed that 1°C increase in mean temperature significantly decreased NFR by Rs. 9869 per hectare showing the adverse impact of increased mean temperature. While, 1 °C increase in minimum temperature significantly benefitted Pakistan by Rs. 4317 per hectare. However Pakistan lost Rs. 29 per hectare from 1 mm increase in total monthly rainfall. Significant losses to NFR were more in 2010-11 in comparison to 1998-99. Likewise, NFR are becoming more elastic to climate change over time showing that Pakistan's suffering from climate change are getting higher over time (Table 4). Pakistan's sufferings from climate change in this study are consistent with that of studies conducted by Ahmed and Schmitz (2011), Shakoor et al. (2011) and Saboor (2014) which showed a decrease in net crop revenues due to warming. However, these results are inconsistent with the Ricardian study conducted by Hanif *et al*. (2010).

Table 4: Marginal effects, elasticities and thresholds from spatial specifications

Climate Normals	Marginal Effects (Rs./Hectare)		Elasticity (%)		Thresholds
	1998-99	2010-11	1998-99	2010-11	
Mean Temperature	-4350.83	-9869.21*	-2.56	-5.82	17.01 (IU)
Minimum Temperature	2171.57	4316.87*	0.87	1.73	12.32 (U)
Maximum Temperature	618.37	3638.21	0.50	2.92	37.24 (IU)
Total Rainfall	-17.67*	-28.92*	-0.22	-0.36	789.53 (U)

* shows significance of marginal effects at 5 percent, Thresholds are based on 2010-11 Ricardian regression

Threshold levels of climate factors

Estimated thresholds provide the optimal levels of temperature and rainfall for agriculture sector in Pakistan. The optimal level of mean temperature for Pakistan was found 17°C with inverted U shape representing that up to 17°C, farmers' NFR will rise and after this they will start to decline for every unit increase in temperature. Threshold level for minimum temperature was 12°C with U shape meaning that after this point, NFR will rise for every unit increase in minimum temperature. For maximum temperature, it is 37°C with inverted U shape meaning after reaching this level of maximum temperature, NFR will start to decline. For precipitation, optimal level is 790 mm with U shape showing that less than 790 mm total monthly rainfall are hurting agriculture and more than 790 mm rainfall will increase NFR in Pakistan (Table 4).

Estimates from Non-Climate Factors

Increase in share of irrigated land, share of small farmers and use of quality seeds will increase NFR in 1998-99 and have non-significant effect in 2010-11 while improved literacy ratio significantly increased farm revenues in 2010-11. The increase share of crop only farming significantly decreased the NFR in both the models. So mixed farming is preferable in all times in Pakistan's context. Explanatory power of both the models is very good indicated by the R-square values and spatial coefficients for all models are also significant providing the support to account for the spatial impacts in the analysis (Table 3).

Conclusion

In a nut shell, climate change is significantly hurting NFR in Pakistan over time. Threshold levels for mean temperature 17°C (IU) and minimum temperature 12°C (U) are already met. Observed mean temperature in Pakistan is 22 °C since further increase in mean temperature is harmful for agriculture in Pakistan and for minimum temperature is 15°C showing increase in NFR for every unit increase in minimum temperature. However, observed mean maximum temperature in Pakistan is 30°C in comparison to estimated threshold level of 37°C (IU) so maximum temperature increase in Pakistan will also increase farm revenues. These findings are confirmed by this study. Observed total monthly rainfall in Pakistan is 464 mm ranges between 118-1525 that is far less than the threshold level of 790 mm (U) so is the reason Pakistan is not benefiting from small increase in rainfall. The significant losses are more to non-significant gains so overall NFR are decreasing due to climate change.

The study suggested mix cropping systems instead of crop only farming to compete the challenging climate change scenario. The small farmers were found to be more efficient in Pakistan in the past. Their deteriorating position in 2010-11 in comparison to 1998-99 is representing that their inadequate resources might not be compatible to growing warming trends. In such situations, introduction and implementation of cooperative farming may prove a good step towards betterment of small farmers by reducing cost of production. Same is case with the use of quality seed showing that seed is also incompatible with climate change. Climate resilient seeds are required to develop for sustainable agriculture development to increase agriculture growth and consequently, economic growth.

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