A Ricardian analysis of the climate change impact on Nepalese agriculture

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Abstract

This paper applies Ricardian approach to measure the effect of climate change on crop production in Nepal using cross-section data of Nepal Living Standard Survey 2003/04 and climate data from Department of Hydrology and Meteorology, Nepal. The study examines the relationship between net farm revenue and climate variables using 656 households of 14 districts covering all climatic zones of Nepal. Net farm revenue is regressed on climate and socio-economic variables. The findings show that these variables have significant impact on the net farm value per hectare. More specifically, relatively low precipitation and high temperature seem to have positive impact on net farm income during the fall and spring seasons. Net farm income is likely to be increased by summer precipitation, but not by temperature. Marginal impacts are mostly in line with the Ricardian model, showing marginally increasing precipitation during summer and winter would increase net farm income, but reduce by the quarter terms and temperature of these seasons. Moreover, marginally increasing precipitation would increase farm income in the hilly region, but reduce in *Terai* region. Other variables such as ratio of irrigated farm land and obtaining credit are found to be positive impact on net farm value but not by farm size. Conclusively, the impact of climate change on agriculture seems to be varied with the temperature and precipitation in different climatic zones.

Keywords: climate change, agriculture, Ricardian approach, marginal impact, Nepal
JEL Classification: C31 Q24 Q54

1. Introduction

There is growing concerned about the effect of climate change on human life, as the scientific consensus grows that significant climate change is very likely to occur over the 21st century (Christensen and Hewitson, 2007). Climate change can have both direct and indirect negative impact on the general well-being of the people in which the community people who depend highly on the natural resources such as agriculture and forest for their livelihoods are likely to be most affected by the climate change. In regards to the agriculture, the general consensus is that

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changes in temperature and precipitation will result in changes in land and water regimes that will subsequently affect agricultural productivity (World Bank, 2003). There is an increasing concerned about the impact of climate change on agriculture in developing countries with changing in global climate (IPCC, 1996) and some attempts have been made to estimate this impact (Winter et al., 1996; Dinar et al., 1998; Kumar and Parikh, 1998; Mendelsohn and Tiwari, 2000). The impact of climate change on agricultural sector is therefore a matter of concerned, particularly in the low income countries where a majority of people are living in rural areas. An understanding of the impact of climate change on agriculture in the developing world is likely to be critical for the distributional effects of climate change as well as the potential benefits of policies to reduce its magnitude.

This paper aims to provide the evidence on the impact of climate change on agriculture in Nepal. The study on the impact of climate change on agriculture seems to be plausible in Nepal due to higher dependency on the agricultural sector for livelihoods. Previous studies on the impact of climate change on agriculture show a prediction of reduction in agriculture yields particularly in tropical regions (Mendelsohn and Dinar, 1999; Kurukulasuriya and Rosenthal, 2003). The literature also shows that climate change would have serious impacts on agriculture in developing countries (Pearce et al., 1996; Tol, 2002; Mendelsohn et al., 2006). These studies further reveal that large adverse impacts on agricultural productivity, especially among small holders who depend on farm productivity for livelihood and subsistence opportunities can lead to a rise in poverty levels (World Bank, 2003). This paper thus intends to add the literature on the economics of climate change as well as contributes to the research on measuring the potential impacts of climate change in low income countries, Nepal in particular.

The studies on the impact of climate change on agriculture have been increasing since last decade in which two main approaches are widely used to assess the impact of climate change (Mendelsohn, 2007); one is simulation models that obtain parameters from controlled experiments and another one is to conduct a cross-sectional analysis observing the (economic) system across different locations in order to determine how the system may adapt to different climates. The second method assessing the impact of climate change is widely known as Ricardian approach which corresponds to the Hedonic Pricing of environmental attributes (Libert et al., 2009). This paper applies the second method to measure the effect of climate change using cross-section data of more than 656 households covering 14 districts representing from all ecological bets of Nepal.

The paper organizes as follows; after providing a background of climate change in the introduction part, overview of Nepalese agriculture is given in Section 2 and Section 3 discusses the method applied to measure the impact of climate change on agriculture, Section 4 presents data sources and descriptive statistics, while the findings of econometric model are given in Section 5, and finally Section 6 concludes.

2. Overview of Nepalese Agriculture

Nepal is traditionally an agrarian country in which subsistence and semi-commercial agriculture dominate in this sector. About 73 percent people are directly and indirectly depend on this sector, out of which more than 63 percent self-employed and 6 percent as wage laborers, however, the share of agricultural sector in the GDP is about 33.7 percent (World Bank, 2008). The variability of agricultural productivity due to climate change may have significant impact on the people depending on this sector; most of them are poor and small holders.

In Nepal, the total cultivated land area available is 2.97 million hectares, out of which, about 0.99 million hectares land area is cultivated. The average land holding is only 0.8 hectares and about 75 percent land holdings have less than 1 hectare in area (CBS, 2002). Despite a small country with a large number of small holders, Nepal is divided into three main climatic zones: alpine (area above 10000 feet from sea level); temperate (area between 2000 to 1000 feet varying temperature between 32 and 100 F); and sub-tropical (area between 200 to 2000 feet with temperature 50 to more than 100 F). The cropping patterns and crops are also different in different climatic zones (often called as agro-ecological belts) such as rice and wheat are the major cereal crops in *Terai*, i.e. the southern plain area, while maize and finger millet are the main crops in the hills and the mountain, especially on marginal lands having low productivity. In addition to traditional and staple crops, there is also growing trend of cultivating other non-staple crops such as legumes, seasonal vegetables, potatoes and other cash crops in the recent years. However, agricultural commercialization has yet to occur in a tangible way. Policy makers and economists often view that the major constraints in the agricultural commercialization including low productivity are due to poor infrastructure and high dependency on weather. Due to lack of sufficient irrigation facility, Nepalese agriculture depends on weather. As the country belongs to the monsoon zone, major staple crops are cultivated in this season, therefore the degree of rainfall has significant impact on productivity and food security in Nepal. The study seems to be plausible to assess the impact of climate (e.g. precipitation and temperature) change on agriculture for the country like Nepal which depends primarily on rain-fed agriculture.

The data on climate change show that the temperature in Nepal is increasing by 0.06 degrees Celsius every year for the last three decades. Moreover, there is a wide variation in temperature and precipitation among the districts and regions.

3. Measuring the impact of climate change on agriculture

This study applies the Ricardian method developed by Mendelsohn et al. (1994) to measure the value of climate in US agriculture. This analysis is based on the assumption of a direct cause and effect relationship between climate events and farm value. This technique is applied under the assumption of perfect competition in which Ricardo observed that land value would reflect land productivity at a site. In other words, Ricardian method has been applied to assess the contribution of environmental conditions to farm income.

Ricardian approach is preferred to the traditional estimation methods, given that instead of ad hoc adjustments of parameters that are characteristic of traditional approach, this technique automatically incorporates efficient adaptations by farmers to climate change (World Bank, 2003). Because, the use of net revenues in the Ricardian approach reflects the benefits and costs of implicit adaptation strategies. More specifically, Ricardian analysis incorporates the substitution of different inputs and the introduction of alternative activities that each farmer has adopted in light of the existing climate (Kurkurlasuriya et al., 2006). The advantage to apply this model is that it is cost effective, since secondary data on cross-sectional sites can be relatively easy to collect on climate, production and socio-economic factors (Deressa and Hassan, 2009).

Despite some strengths, the Ricardian method as a cross-section analysis does not account for dynamic transition costs which can occur as farms move between two states. Likewise, Ricardian approach is failure to fully control the impact of important variables that could also explain the variation in farm incomes. Another criticism of this method is that the assumption of constant prices is wrong (Cline, 1996), because the inclusion of price effects is problematic and the Ricardian approach is weaker for it (Mendelsohn et al., 1994). However, these problems are significant but not fatal (Mendelsohn, 2001).

The analysis of climate change impact on agriculture applying the Ricardian approach uses net farm revenue as a dependent variable, a more robust measure given concerns about equilibrium as it measures what the farmer currently receives without any concerns for future returns, discounting, capital or labor markets (World Bank, 2003). It is often mentioned in the literature that the Ricardian theory is consistent when net revenue instead of land value is used, because land values are based on the discounted stream of future net revenues (Kurkurlasuriya and Ajwad, 2006). As the data on the worth of net revenue are based on the cross-section survey of the year 2003/04, we ensure that the survey year is not influenced by any unusual, year specific, climatic activity that can otherwise be problematic if both prices and productivity are affected. Moreover, Ricardian model seems to be plausible in developing countries due to insufficient research and experiments to apply other models such as agro-economic model (Seo et al., 2005).

The Ricardian approach followed by Mendelsohn et al. (1994, 1999) is the net revenue function of the form:

(1) $$\Pi = \sum P_i Q_i (X, C, Z) - \sum P_x X$$

where Π is the net revenue per hectare, P_i is the market price of crops i, Q_i refers to the output of crop i, X is the vector of purchased inputs, C is a vector of climate variables, Z is a set of household and land characteristics, and P_x is a vector of input prices.

The Ricardian model is based on the assumption that farmer will maximize net farm revenue by choosing inputs (X) subject to climate and other socio-economic variables. In other words, this model is applied only when we expect farmers to be price takers in all markets. If this assumption violated, the estimates of the function are meaningless from an economic point of view. Therefore, the standard Ricardian model is presented in a non-linear function of the form where net farm value per hectare is regressed on climate and other socio-economic variables:

(2) $$\Pi = \alpha_0 + \alpha_1 C + \alpha_2 C^2 + \alpha_4 Z + \mu ,$$

where μ is the error term.

Marginal values are often calculated to measure the marginal impacts of a change in climate variables and these values depend on the regression equation which is being used and the climate which is being evaluated. The expected marginal impact of a single climate variable, C_i on net farm income evaluated at the mean is:

(3) $$E[\partial \Pi / \partial C_i] = \alpha_{1,i} + 2 * \alpha_{2,i} * E[C_i],$$

in this equation, the linear formulation of the model indicates the uni-directional impact of the independent variables on the dependent variable, while nonlinear term shows the non-linear shape of the net revenue of the climate response function. It is noteworthy to say that the net revenue function is U-shaped in case of quadratic term being positive and hill-shaped in case quadratic term being negative.

4. Data sources and analysis

The study uses data obtained from the Nepal Living Standard Survey 2003/04 (NLSS II) of the Central Bureau of Statistics, Nepal. The methodology used in the NLSS II was applied more than 50 developing countries by the World Bank with the purpose of the Government to monitor progress in improving living conditions and to evaluate the impact of government policies and programs in the country. NLSS II is the second national survey of Nepal conducted by the Central Bureau of Statistics, Nepal with technical and financial cooperation from the World Bank. The survey was applied two-stage sampling procedure to select the sample for the first stage of the survey (e.g., NLSS 1995/96), in which the smallest administrative unit (i.e. the ward of Village Development Committees) was considered as the primary sampling unit (PSU) for the survey.

The NLSS II was selected 275 wards with probability proportional to size (PPS) from each of the four ecological strata, where size was measured from the number of households in the ward. For NLSS II, the number of households in each PSU was fixed such as twelve. The total sample size was 4008 households. However, only 3912 households consisting of 408 households from mountain; 1968 households from hills; and 1632 households *Terai* (the southern plain) were enumerated because of insurgency during field survey. Out of 3912 households, this study uses only the 656 households of 14 districts for this analysis.

NLSSs provide a large number of data set about agricultural activities including the information of demographic characteristics, household activities both farm and off-farm, education and literacy, employment status in both farm and off-farm, wage rates and remittances covering all administrative and ecological zones. For the purpose of this study, information includes the farm size, farm income, cost of inputs, household size, farm credit, distance of input market, and location characteristics.

In addition to household data, climate data such as temperature and precipitation were obtained from the Department of Hydrology and Meteorology, Ministry of Environment, Nepal in which the data consist of 30 years from 1977 to 2006.

Descriptive statistics of the data used in this paper are given in Table 1. Net crop output[3] is the income received from farm products and by products of farm minus the total input cost including labor, fertilizer, seed and other costs in Nepalese Rupees. In other words, the total input cost is the cost paid by farm household either in cash or in kind. Total farm land is the land used by the household for agricultural activities either owned, or rented, or sharecropped during the survey year and measured in hectare. Irrigation ratio is considered as the measurement of land quality which is common in these exercises.

The results of means and standard deviations show that despite a small country in size, there are wide variations in precipitation and temperature in Nepal. Variations in means and standard deviations are also found in net farm income per hectare, age and family size.

5. Econometric results

The results of Ricardian models present in Table 2, showing both marginal impacts of the quarterly precipitation rates and temperatures (in Model 1). However, some of quarterly temperatures are omitted from the model due to problem of collinearity. In Model 2, we include

[3] This paper frequently uses both net farm income and crop output, representing same meaning. Do not consider different meanings and values.

other socio-economic and land characteristics in order to find out the impact of such characteristics on the net farm revenue per hectare. As we discussed earlier, the dependent variable of the model is net farm income per hectare (in Nepalese currency, i.e. NRs.), while exogenous variables are precipitation rates, temperatures and other socio-economic characteristics. The second model includes farm size and ratio of irrigated land, assuming that irrigated land is considered as high quality of land, so ratio of irrigated land is a proxy for land quality. The variables such as distance to input markets and obtaining farm credit are often deterministic factors for agricultural productivity, particularly in the developing world, so we include these variables in the analysis. In addition, socio-economic characteristics such as household size, age, sex and education level of the household head are included in the model, implying that such variables do matter in the agricultural productivity. For instance, age of the household is often used as a proxy variable for farm experience.

Prior to the econometric specification, we conducted several diagnostic tests. First we perform normality test in residual by the Shapiro-Wilks asymptotic test which is rejected, revealing that estimated coefficients are consistent. Second, since the data set is cross-section and covers wide variation in the region, the probability of heteroscadasticity is high. So we perform heteroscadasticity test (Breusch-Pagan / Cood Weisberg) and there is presence of heteroscadasticity, then we report robust standard errors in the estimated coefficients.

The Model 1 which displays the marginal impacts of climate variables on net farm income per hectare is presented in Table 2. The marginal effects of precipitation and temperature are calculated at mean for each sample. The R^2 value (0.10) shows that climatic variables explain about 10 percent of variation in farm value, while F-statistic implies the function to be well behaved.

The findings of Model 1 show that most estimated coefficients are significant at required levels. The results of marginal impacts show that precipitation in the summer and winter has positive impact on farm value (i.e. increasing returns), while spring and fall precipitations have negative on farm value (indicating diminishing returns). The square terms reveal that doubling the spring and fall precipitation can lead to positive impact on farm value, but winter and summer precipitation squares lead to reduction in the net farm income.

The Model 2 estimates the econometric equation incorporating climate and other socio-economic variables, the R^2 value explains about 11 percent of variation in net farm revenue per hectare. The test result of F-statistic shows the function to be well-behaved. The findings show that most estimated coefficients of climate combined with some socio-economic variables are significant, implying the impact of these variables on farm value. For instance, there is positive impact of spring and summer precipitations on farm income, but negative impact of fall precipitation. Strong positive impact of spring and fall temperatures are found in net farm revenue, while as expected, summer temperature has negative impact on farm value. However, the negative impact of winter temperature on farm value is a bit surprising at least in this data set. The intuition behind the negative impact of winter temperature may be due to low productive crops such as wheat planted in the winter season. The productivity of winter crop may be low in the mountain and hilly region due to high cold. This result needs to interpret with caution. The findings of other variables show mixed results. For instance, higher farm output is observed on irrigated farmland compared to non-irrigated farm land, but productivity is high on small farm than the large farm, showing inverse farm size and productivity relationship. Farmers who obtained credit increase farm income, showing the common problems in low-income countries where credit is one of the constraints for small farm holders. The coefficient of head's education is significant and negative, implying negatively related to net farm income. This result seems to be a bit surprising, probably educated people preferred to work in the off-farm sector due to low wages and returns in the agricultural sector. Moreover, other variables such as sex and age of household head, distance to input markets and family size are not significant at any required level, indicating no impact of these variables on farm value at least in this model and data set.

Despite few surprising results of the precipitation and temperature, the results are found to be in line with the conventional hypothesis of climate change impact on agriculture, implying that rising temperature is likely to reduce farm output. Negative impact of fall and spring precipitation on farm value seems to be reasonable in Nepalese context, because these two seasons are the period of harvesting major crops such as paddy rice and maize (in fall) and wheat (in spring). If relatively high precipitation occurs during these seasons, then there is high probability of damaging crop output during the harvest time. On the other hand, high temperature with low precipitation during spring and fall is more likely to be supportive for timely harvesting the cereal crops and reducing loss of crop output. Positive impact of summer precipitation is also plausible because of high dominancy of rainfed agriculture in Nepal, indicating that timely precipitation in the summer helps to plant paddy rice and other seasonal crops on time thereby increase productivity.

Marginal effects of climate change on agriculture are also evaluated among the ecological belts such as mountain, hills and *Teria* (see Table 3). Annual average precipitation is likely to increase crop value in the hilly region, but reduce in the *Terai* region. Temperature has positive impact on farm value in alpine and temperate zones and negative in sub-tropical zone, but these coefficients are not statistically significant at any required level. However these findings indicate some trends how the impact of temperature and precipitation on net farm income per hectare varies in different climatic zone.

6. Conclusions

Climate change is widely acknowledged as the global concerned due to its large effects on human life. Climate change can have multiple impacts on livelihoods of the people. For instance, impacts of climate variability and change on agricultural sector are projected through changes in land and water regimes, the likely primary conduits of change. Therefore, it is obviously a matter of concerned for policymakers and economists regarding its impact on the livelihoods.

This paper thus aims to shed light on the impact of climate change on Nepalese agriculture using cross-section data of 656 farm households across 14 districts covering all climatic zones of Nepal. The study applies Ricardian approach to measure the impact of climate change on agriculture in which net crop output is regressed only with climate variables in Model 1 and then with both climate and other socio-economic variables. The explanatory variables include the linear and quadratic terms of precipitation and temperature for the four seasons (winter, spring, summer and the fall), household variables, land and ratio of irrigated land. The paper also calculates marginal impacts of climate change on agriculture both on the basis of season and climatic zone in order to explore the variation of effects on different seasons and climatic zones. We are careful to handle some of the estimation problems such as multicollinearity and heteroscadasticity, often arisen on cross-section data in the application of nonlinear models.

The findings show a significant impact of climate variables on net farm income per hectare across Nepalese farm households, indicating both positive and negative impact of precipitation and temperature. Net farm income is likely to increase with low precipitation and high temperature during the fall and spring seasons which are the major harvesting seasons of Nepal. Farmers are likely to increase their revenue with relatively low temperature and enough precipitation during the summer period. Other socio-economic variables have also impact on net farm income. For instance, net farm income is likely to be high on irrigated farm land combined with obtaining farm credit. But small farms manage better and obtain higher net income per hectare than large farms.

The marginal impacts of climate change on agriculture are found to be in line with the second model. However there are few variations in the marginal impacts. For example, winter precipitation has positive impact on farm value in Model 1, but not significant on Model 2, while winter temperature has negative impact on farm value. The quadratic terms of spring and fall precipitations have positive impact on net farm income per hectare, but not in summer and winter precipitations. Likewise quadratic term of fall temperature is likely to increase net farm income. The marginal impacts based on the climatic zone are found few significant variables. Annual precipitation is likely to increase crop output in hills, but reduce in *Terai*.

Finally, the study only focuses on the impact of climate change on agriculture using Ricardian approach, we found some interesting results to understand the impact of climate change on Nepalese agriculture. As there is a variation in the impact of the climate change (i.e. change in precipitation and temperature) on agriculture in different seasons and climatic zones, the policy needs to address these variations while formulating the adaptation and mitigation strategies of the negative impact of climate change in the country. Since, this study applies only a Ricardian approach to measure the impact of climate change on agriculture, further research and study using more advanced models, such as agro-economic and CGE models to measure the impact of climate change on agriculture is needed.

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APPENDIX

Table 1: Descriptive statistics

Variables	Variable description	Mean	Std. Deviation
Net farm income	Income from farm products plus sale of animal income and other products (in Nepalese Rupees)	2572.86	25182.64
Farm size	Farm land both owned and sharecropped (in hec)	0.74	1.06
Irrigratio	Ratio of irrigated land on total farm land	0.51	0.44
Age	Head's age	46.47	14.38
Sex	Head's sex	0.81	0.38
Edulevel	Years of schooling of household head	3.60	4.37
HHsize	Total number of household members	5.3	2.5
Mktcenter	Distance to input markets (walking hours)	0.41	0.25
Farm loan	Whether or not farmer received loan	0.62	0.48
w_preci	Winter precipitation (December-February) (mm)	23.24	9.22
w_temp	Winter temperature (December-February) (°C)	11.94	3.84
sp_preci	Spring precipitation(March-May) (mm)	57.26	33.63
sp_temp	Spring temperature(March-May) (°C)	22.36	5.44
su_preci	Summer precipitation (June-August) (mm)	589.59	298.75
su_temp	Summer temperature(June-August) (°C)	25.46	4.27
fal_preci	Fall precipitation (September-November) (mm)	78.29	45.55
fal_temp	Fall temperature (September-November) (°C)	21.51	4.95
Total observations			**656**

Table 2: Regression equations of the determinants of net farm revenue

Variables	Model 1	Model 2
Winter precipitation	649.77***	-19.53
	(3.63)	(1.56)
Winter precipitation square	-9.63***	
	(3.44)	
Spring precipitation	-259.15**	12.96***
	(2.78)	(4.02)
Spring precipitation square	1.01**	
	(2.73)	
Summer precipitation	101.21***	4.67***
	(4.02)	(4.58)
Summer precipitation square	-0.10***	
	(3.76)	
Fall precipitation	-261.09***	-31.02***
	(3.47)	(4.46)
Fall precipitation square	3.50***	
	(3.56)	
Winter temperature	-1192.1*	-713.4***
	(1.95)	(3.42)
Winter temperature square		
Spring temperature	523.25	891.15***
	(1.48)	(3.83)
Spring temperature square	-17.07	
	(1.40)	
Summer temperature	-943.16***	-468.43**
	(4.01)	(3.19)
Summer temperature square		
Fall temperature	1014.55*	26.53
	(1.78)	(0.7)
Fall temperature square		
Farm size		-184.51**
		(2.22)
Ratio of irrigated land in the total land		545.39**
		(2.65)
Distance to input market		-55.34
		(0.15)
Farm credit		516.19**
		(2.20)
Age of household head		4.78
		(0.66)
Sex of household head		17.15
		(0.7)
Education level of household head		-45.92*
		(1.67)
Household family size		51.56
		(0.79)
Constant	-7702.68	-828.87
	(1.19)	(0.78)
R-squared	0.10	0.11
F-statistics	$F_{(13, 634)}$=7.32***	$F_{(16, 639)}$=6.39***
Total observations	656	656

***, **, * 1, 5 and 10 percent level of significance respectively. t-statistics are given in the parentheses. Some square terms of climate variables omitted in Model 2 due to problems of multi-collinearity.

Table 3: Marginal impacts of climate change on agriculture in different climatic zones

	Mountain (alpine zone)	Hills (Temperate zone)	*Terai* (semi-tropical zone)
Temperature	19.34	15.55	-211.56
Precipitation	-3.69	1.36*	-24.93**

** and * 5 & 10 percent significant level.