ECONOMIC IMPACT OF CLIMATE CHANGE ON VIETNAMESE CROP FARMING: A RICARDIAN MODEL

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The Ricardian model is used for estimating economic impacts of climate change on crop farming business in Vietnam. Analyses show that higher temperature and rainfall reduce net income of peasants. Temperature, however, has a non-linear impact on the net income (some 80%) while the impact of rainfall is unidentifiable. The scenario of climate change in Vietnam implies a prediction that when the temperature rises 1.5^{0}C – 2.9^{0}C and the rainfall rises by 3.4% - 6.6%, the Vietnamese agriculture will suffer a loss of VND2.000 – 3.700 billion. Accordingly, its GDP will fall by 0.6% - 1.3% (if it rises by 3% per year on average) by the end of the century (2100).

Keywords: climate change, Vietnamese agriculture, Ricardian model, economic impact

1. Introduction

Temperature, rainfall and other climatic factors are changing in an increasingly unpredictable and drastic manner affecting output, income and health of communities at present and their future development as well. Agricultural production is affected most severely by the climate change. Compared with developed countries, agricultural production in developing countries suffers greater damage because of their poorer infrastructure and adjustability (World Bank 2010). Researchers of economic impacts of climate change on agricultural production in China, India, Latin America and Africa in the past 20 years usually use the Ricardian model and gain results useful for making of adaptation policy in these countries.

In Vietnam, agriculture plays a key role in economic development and food security. Studying impacts of climate change on agriculture may help change the attitude towards this problem and quantify these impacts, thereby supporting the making of a timely adaptation program. At present, many questions are the center of attention, such as (1) Do changes in temperature and average rainfall affect output and income of peasant families? (2) What is the trend of these impacts? and (3) How serious is damage to crop farming business in the coming years?

Samples for the research include peasant families. Data about them are from results of the Vietnam Household Living Standards Survey (VHLSS) 2008. Total samples are 3,616 selected from 9,189 peasant families. Meteorological data are collected in the period from November of 2007 to October of 2008 by 115 stations all over Vietnam. The data are processed, and observations whose means are beyond the range equaling two times of standards deviation are rejected.

Objectives of the research are: (1) Identifying effects of changes in average temperature and rainfall on peasant families and crop farming business; (2) Identifying trends of their impacts; and (3) Predicting damage to agricultural production in future according to scenarios for Vietnam.

2. Theoretical basis

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Ricardian model is a micro-econometric one (Seo & Mendelsohn, 2008) that usually employ cross-sectional data (Kurukulasuriya & Mendelsohn, 2008) to analyze impacts of the climate change. It is developed from the model analyzing value of land reflected in its productivity presented by David Ricardo (1772-1823). In this model, net income of peasant families or land value shows itself in land productivity. The basic Ricardian model (1) implies that peasants' net income (NI) depends on factor inputs (T), weather (W), hydrographic features (H), soil (S), and socioeconomic characteristics of peasant family (C), output (q), price of farm product (P_q), and prices of factor inputs (p_t).

$$NI = \sum p_q * q(T,W,H,S,C) - \sum p_t * T \quad (1)$$

According to the theory of profit function, this research assumes that peasant families always try to maximize their profit based on existing conditions of factor inputs; and that they will select crops, farming plans and inputs in a manner that allows a maximum profit. Thus, the value of output q will be a function of factor inputs (T), such as labor, fertilizer, and crop protection drugs; weather (W) including temperature and rainfall; socioeconomic characteristics of peasant families (C); soil (S) including farming area and fertility; hydrographic features (H); and other factors represented in equation (2):

$$q = f(T,W,C,S,H,K) \quad (2)$$

And the profit function (net income) can be presented as follows:

$$NI_{(T,W)} = p_q * q(T,W,C,S,H,K) - pt*T \quad (3)$$

As analyzed above, profit maximization depends on factor inputs and output of production process and other production factors (K), and the profit function change into the following form:

$$NI(p_q, p_t) = \max_{q,T} [p_q q - p_t T: (q,T) \in M; p_q, p_t > 0] \quad (4)$$

where M is a production factor.

The input demand function of a peasant family (T) depends on market prices of inputs and expected prices of output influenced by weather and other factors (K) via the following equation (5):

$$T = f(p_q, p_t, W, K) \quad (5)$$

Prices of inputs and output in the Ricardian model are *the expected prices on all markets*. This is an important hypothesis of this research. If it is rejected, the research becomes worthless because estimates of the model have no meaning. In short, the basic model can be expressed in the following:

$$NI = \beta_0 + \beta_1 W + \beta_2 W^2 + \beta_3 H + \beta_4 S + \beta_5 C + e_i \quad (6)$$

where e_i denotes residual of the model; W is the vector of weather variables employing linear and non-linear forms; H is the vector of characteristics of peasant family; S is the vector of variables related to land and land use; and C is the vector of variables representing sources of water and hydrographic features.

3. Ricardian model for Vietnam

The Ricardian model for Vietnam (7) is developed from the model (6). Besides variables "temperature" and "average rainfall" (in their non-linear forms) in dry and rainy seasons, a new variable (interaction between average temperature and rainfall in two seasons) is used to analyze their combined impacts on the net income. This is the difference between the Ricardian model for Vietnam and similar ones used for other countries.

$$NI_i = \beta_{0i} + \beta_{1i} Td_i + \beta_{2i} Td^2_i + \beta_3 Rd_i + \beta_4 Rd^2_i + \beta_{5i} Tw_i + \beta_{6i} Tw^2_i + \beta_{7i} Rw_i + \beta_{8i} Rw^2_i + \beta_{9i} T_{di} * R_{di} + \beta_{10i} T_{wi} * R_{wi} + \beta_{11i} Age_i + \beta_{12i} Edu_i + \beta_{13i} Sex_i + \beta_{14i} Area_i + \beta_{15i} Mcrop_i + \beta_{16i} Mland_i + \beta_{17i} Lland_i + \beta_{18i} Irri + e_i \quad (7)$$

Definition, unit and other characteristics of variables in the model are presented in Table 1.

4. Marginal impact and its trend

From equation (7) of each weather variable, we have:

+ Marginal impact (MI) of dry season average temperature on net income of a peasant family:

Table 1: Variables in the Ricardian model

Symbol	Definition	Unit	Expected sign
NI	Net income per year from crop farming: total income from crop farming minus total expenditure on crop farming	VND1,000	Dependent variable
Td	Dry season average temperature	^{0}C	(+/-)
Td^2	Squared dry season average temperature	$(^0C)^2$	
Rd	Dry season average rainfall	mm	(+/-)
Rd^2	Squared dry season average rainfall	mm^2	
Tw	Rainy season average temperature	^{0}C	(+/-)
Tw^2	Squared rainy season average temperature	$(^0C)^2$	
Rw	Rainy season average rainfall	mm	(+/-)
Rw^2	Squared rainy season average rainfall	mm^2	
$T_d{}^*R_d$	Interaction between temperature and rainfall in dry season	Interaction variable	(+/-)
$T_w{}^*R_w$	Interaction between temperature and rainfall in rainy season	Interaction variable	(+/-)
Age	Householder's age	Year	(+)
Edu	Householder's schooling years	Year	(+)
Sex	Householder's gender (male = 1, female = 0)	Dummy variable	(+)
Area	Crop farming area of peasant family	Ha	(+)
Mcrop	Mode of crop farming (polyculture = 1, monoculture = 0)	Dummy variable	(+)
Mland	Size of farming area of an average family (1ha < Mland <2.5ha) = 1, otherwise = 0	Dummy variable	(+)
Lland	Size of farming area of a large family (Lland $\geq$ 2.5ha) = 1, (Lland $\leq$ 2.5ha) = 0	Dummy variable	(+)
Irri	Family with sources of water for crop (canals, pumping machines, manual watering), and family without available source of water and dependent on rain water. Irri = 1 if water is available; Irri = 0 otherwise	Dummy variable	(+)

$$MI_{Td} = \frac{dNI}{dTd} = \left[\beta_1 + 2\beta_2 Td + \beta_9 Rd\right] \quad (8)$$

It can be expressed differently: From equation (5), when Td_{tb} changes one unit (Td_{tb+1} = T_{tb} increases 1^0C), or MI_{Td} moves to MI_{Td+1}.

We get:

$$\Delta MI_{Td} = MI_{Td+1} - MI_{Td} \quad (9)$$

Combining (8) and (9) and assuming that other factors remain unchanged, we have:

$$\Delta MI_{Td} = \left[\beta_1 + 2\beta_2 (Td_{tb+1}) + \beta_9 Rd\right] - \left[\beta_1 + 2\beta_2 Td_{tb} + \beta_9 Rd\right] \quad (10)$$

where ΔMI_{Td} indicates the net income of peasant family that changes when the dry season average temperature changes by one unit (increasing 1^0C) in a given length of time and this is value of marginal impact of dry-season temperature on the net income of peasant family. Values of marginal impact from other weather variables are worked out in a similar way:

* Marginal impact of average temperature of a year (ΔMI_T) on net income:

$$\Delta MI_T = \Delta MI_{Td} + \Delta MI_{Tw} \quad (11)$$

* Marginal impact of yearly rainfall (ΔMI_R) on net income:

$$\Delta MI_R = \Delta MI_{Rd} + \Delta MI_{Rw} \quad (12)$$

where ΔMI_{Td} and ΔMI_{Tw} are values of marginal impact of dry-season average temperature and rainy-season one when the rainfall rises/falls one unit (1mm a month); and ΔMI_{Rd} and ΔMI_{Rw} are values of marginal impact of dry-season and rainy-season rainfall.

Trend of impact of changes in dry-season temperature on peasant net income is expressed in the following quadratic line (with the assumption that other factors remain unchanged):

$$NI = \beta_1 [Td] + \beta_2 [Td]^2 \quad (13)$$

Trend lines for rainy-season temperature, rainfall in rainy and dry seasons are worked out in the similar way.

5. Scenarios of climate change and impact forecast

This research employs the scenarios of climate change suggested by the Ministry of Natural Resources and Environment (2009) after some adjustments are made to make it appropriate to the research. Calculations, however, do not affect value of the scenario. As recommended by the MNRE, the medium scenario of climate change (B2) is chosen (see Table 2).

Table 2: Scenario of climate change in Vietnam (B2)

Year	2030	2050	2070	2100
Temperature (^{O}C)	0.6	1.1	1.6	2.3
Rainfall (%)	1.5	2.7	3.8	5.2

Value of impact is worked out by the formula:

$$TV_j = \Delta MI_{ha} * X_j * DT(ha) \quad (14)$$

where TV_j represents total value of forecast impact of changes in temperature of rainfall in years corresponding to the scenario of climate change in Vietnam; ΔMI_{ha} is value of marginal impact of peasant family transformed into farming area (ha); X_j is value of changed climate in scenario of the year j; and DT(ha) denotes farming area.

6. Business of crop-growing peasants

Of 3,616 surveyed crop-growing peasant families, 3,100 enjoy available sources of water for their crops and 516 ones depend totally on rain water. The first group lives in lowlands and grows such crops as rice and vegetables; and two major deltas (Hồng and Mekong) house some 90% of these families. The second group lives in highlands and grows mostly perennial plants, such as cashew, rubber, coffee, and certain kinds of fruits. Northwest and Eastern South zone house over 55% of them.

In the North and Central Vietnam, the average farming area per family is below 0.3 ha (except for Northwest where the figure is 1.11ha) compared with 1.3 ha per family in the South (this figure is 1.18 ha in the Mekong Delta). The highest average farming area is found in Western Highlands (1.45ha). The national average, therefore, is 0.66ha. This figure is 0.57ha among families of the first group and 1.21ha for the second group.

The national average net income is VND13.585 million for a crop-growing family. This figure is higher among families of the first group and lower among others (with a statistical significance smaller than 10%). The annual net income varies over zones and modes of irrigation. In Northeast, Northwest and central coastal zones, net income of families of the second group is higher than that of families of the first group. The reverse of this situation is found in Western Highlands and the Mekong Delta.

7. Results of the analysis of the Ricardian model for Vietnam

Coefficients of the Ricardian model in three separate models for Vietnam - General model, Model of peasants with sources of water and Model of peasant without sources of water - are estimated with OLS. Results are as follows.

Tests for correlation coefficients are conducted properly. Results of F tests for three models are 584.78; 772.95; and 33.12 respectively. Thus the models are fit and not all independent variables lack ability to explain changes in net income in each model. The adjusted R^2 in three models are

Table 3: Regression for three models

Dependent variable: Net income (VND1,000/family)

Model/ Variable	General		With sources of water		Without sources of water	
	Beta	t-Stat.	Beta	t-Stat.	Beta	t-Stat.
(Constant)	-36,429.38	-0.986	-66,658.96	-1.81**	54,010.43	0.45
Td	-2,238.64	-1.55	-559.32	-0.36	-5,412.85	-1.45
Td2	59.63	1.90*	10.92	0.32	168.13	2.05**
Tw	4,444.95	1.67*	6,627.24	2.60**	-1,001.87	-0.11
Tw2	-95.25	-1.71*	-135.04	-2.53**	-31.03	-0.16
Rd	164.59	2.49**	28.93	0.46	559.23	2.17**
Rd2	-0.22	-1.08	-0.09	-0.43	-0.48	-0.62
Rw	-154.86	-2.02**	-114.30	-1.45	-251.68	-1.03
Rw2	0.03	0.71	0.09	2.28**	-0.28	-1.54
Td*Rd	-6.19	-2.20**	-0.78	-0.28	-24.21	-2.51**
Tw*Rw	4.85	1.83**	1.98	0.71	16.78	1.99**
Mcrop	-223.54	-0.43	541.38	1.16	-4,372.37	-1.93**
Sex	499.14	0.84	561.23	1.05	560.37	0.21
Age	43.59	2.34**	35.29	2.10**	-39.04	-0.54
Edu	364.68	5.17***	175.59	2.62***	563.54	2.17**
Area	21,801.19	74.92***	21,804.44	83.50***	21,163.87	15.40***
Mland	-3,690.59	-4.63***	-822.50	-11.75***	-9,248.70	-3.48***
Lland	-27,641.36	-16.32***	-1,981.24	-1.05	-3,7341.80	-6.07***
Irri	5,951.67	8.67***				
Observations	3,616		3,100		516	
F test	584.78		772.95		33.12	
Adjusted R^2	0.744		0.809		0.515	

Note: * significant at 10%; ** significant at 5%; *** significant at 1%.

74.4%, 80.9% and 51.5% respectively. This suggests that variables in each model can explain changes in net income in the corresponding model to a certain extent.

a. Relation between net income and weather:

Effects of weather on net income show themselves in the following findings:

Dry season average temperature (Td) is 21.32^0C and rainy season average temperature (Tw) is 27.11^0C and they have non-linear impacts on the net income.

Dry season average rainfall (Rd) is 49.52mm per month and rainy season average rainfall (Rw) is 273mm per month, and they have impacts on the net income but their non-linear impacts are not clear.

Close examination of coefficients of interaction variables between temperature and rainfall in each season shows that impacts and changes (increases or decreases) have negative relations with peasant's net income in the dry season and positive relations with net income in rainy season. Generally, temperature has clear non-linear impacts on the net income while non-linear impacts of rainfall are unidentifiable.

b. Effects of land and socioeconomic factors:

Effects of other factors in models (Table 3) on the net income are as follows:

- Gender of householder in all three models has no statistical significance, which means that the effect of gender of householder on net income is unidentifiable.

- Householder's age: This factor in the general model and the model of peasants with sources of water is statistically significant at 5% and directly proportional to net income.

- Householder's education has a positive relation with net income.

- As for peasants without sources of water, those who apply monoculture earn VND4,372,387 per year higher than those who apply polyculture with the assumption that other factors are unchanged.

- When the farming area increases, the annual net income rises in three models are similar. Farms of medium and large sizes earn smaller income than small-size farms: VND3,690,593/year and 27,641,362/year respectively (both of them are statistically significant at 1%). This suggests that small-size farms usually gain better business performance.

c. Comparison between two groups of peasants:

Peasants of the second group have bigger farming area and higher net income. Differences in impacts of weather on their businesses are not important (Table 4).

Marginal impacts on the two groups are opposite: marginal impact of temperature on peasant with sources of water and their net income are of opposite signs while impact of rainfall and net income are of the same sign. Contrariwise, in the group of peasants without sources of water, marginal impacts of temperature and net income are of the same sign while impacts of rainfall and net income are of opposite signs. In other words, net income of the first group of peasants falls while that of the second group rises when temperature and/or rainfall increases.

d. Value of marginal impact of weather on net income:

Table 5 shows that marginal impacts of temperature and rainfall have opposite signs from net income. This means that the net income falls when temperature and/or rainfall rises. Values of marginal impacts have opposite signs over seasons: impacts have the same signs as net income in the dry season and opposite signs in rainy season. Value of marginal impact of temperature in rainy season is rather high and therefore the impact for the whole year depends on sign of this value.

Table 5: Marginal impact of temperature and rainfall on net income (VND1,000/family/^{0}C and VND1,000/family/mm/month)

	Temperature	Rainfall
Whole year	-71.24	-0.38
Dry season	119.26	-0.44
Rainy season	-190.50	0.06

e. Trend of impacts:

Table 4: Impacts of climate change on two groups of peasants

Indicator	With sources of water	Without sources of water
1. Net income (VND)	1. 13,117,000	1. 16,396,000
2. Farming area	2. 0.57ha/family	2. 1.21 ha/family
3. Dry/ rainy season temp.	3. 21.32 / 27.24 (^{0}C)	3. 21.29 / 26.38 (^{0}C)
4. Dry/ rainy season rainfall	4. 47.3 / 271.1 (mm)	4. 62.7 / 285.6 (mm)
5. MI_{Td} / MI_{Tw} /MI_T (VND1,000đ/^{0}C)	5. 21.84 / -270.08/ -148.22	5. -62.06 / 336.26/ 274.20
MI_{Rd} / MI_{Rw}/MI_R (VND1,000đ/mm/month)	-0.16 / 0.18/ 0.02	-0.96 / -0.56/-1.52

Impacts of annual rainfall are non-linear and have opposite signs from net income. Their signs, however, are similar to sign of net income in dry season and different from that in rainy season. The trend of impact is a concave curve in dry season and a convex one in rainy season. As for the marginal impact for the whole year, it follows the trend of the rainy season because the marginal impact in the rainy season is much greater than the dry season one.

The trend of impact of temperature on net income is as follows: when temperature rises the net income falls; and the net income reaches its peak when temperature is 30.9^{0}C and falls gradually afterwards.

The diagram expressing the tendency of changes in net income according to changes in the rainfall shows that impact in the rainy season has an opposite sign from income and the same sign in dry season but non-linear impacts in the two seasons are not clear. Sum of impacts in two seasons is similar to the impact of rainfall for the whole year. The trend line of impact is convex, when the rainfall rises and the net income falls to the lowest point corresponding to a rainfall of 25.3mm per month.

f. Forecast of impacts:

Value of impact from changes in temperature and rainfall according to the scenario B2 could be worked out from (15) (see Table 6). By the end of the century when the rise in the temperature is estimated at 2.3^{0}C and rainfall increases by 5.2%, total damage to the agriculture is estimated at VND3,062 billion. Temperature rise accounts for 80% of the damage. According to lowest to highest scenarios, when the average temperature rise is expected to reach somewhere between 1.5^{0}C and 2.9^{0}C and rainfall rises by 3.4% - 6.6%, the damage to Vietnamese agriculture varies between VND2,000 and 3,700 billion, equaling 0.6% - 1.3% of the GDP by the end of the century (if the GDP rises by 3% on average in the years 2008 – 2100).

Farming area in the Hồng Delta is rather

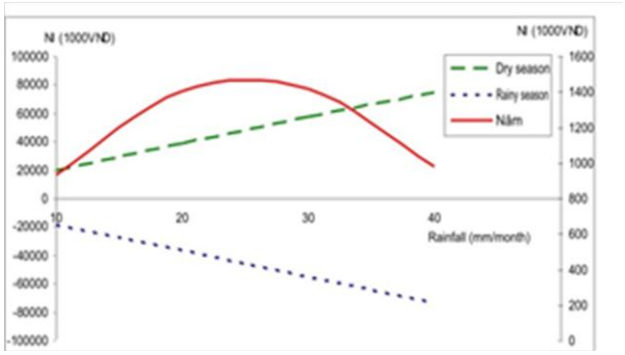

Figure 1: Marginal impact of temperature on net income

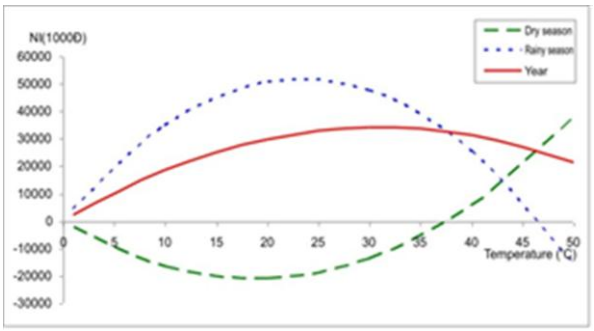

Figure 2: Impact of rainfall on net income

Table 6: Forecast of impact of temperature and rainfall on agricultural production (VND billion)

Zone	Area		2050				2100			
	(1,000ha)	%	Temp.	%	Rainfall	%	Temp.	%	Rainfall	%
Hồng Delta	794.7	8	-295	25	-95	33	-591	25	-184	33
Northeast	760	8	-185	16	-57	20	-370	16	-111	20
Northwest	660.4	7	-51	4	-18	6	-106	5	-34	6
Northern Central										
Vietnam	764.4	8	-240	21	-68	24	-448	19	-130	23
Southern Central										
Vietnam	1,001.5	10	-173	15	-48	17	-366	16	-90	16
Western										
Highlands	1,667.5	17	-65	6	-6	2	-130	6	-12	2
Eastern South	1,393.6	15	-75	6	-6	2	-149	6	-11	2
Mekong Delta	2,550.7	27	-154	13	-12	4	-308	13	-22	4
Vietnam	9,592.8	100	-1,238	100	-310	100	-2,468	100	-594	100

small (representing some 8% of the farming area of Vietnam) in comparison with other zones but it suffers the biggest damage (over 25% of forecast damage). Contrarily, the Mekong Delta representing 29% of Vietnam's farming area only account for some 4% of the total damage estimated for Vietnam. Zones from Northern Central Vietnam towards the North account for some 70% of total damage. In zones where the average farming area per family is larger than 1 ha (Northwest, Western Highlands, Eastern South and Mekong Delta) account for 15% of total damage. In short, damage in the North is greater than that in the South; and impact is more serious in zones where the average farming area per family is small.

8. Conclusion and policy suggestions

Analyses show that both temperature and rainfall produce impacts on the net income of peasant families. The temperature has an apparent non-linear impact on the net income while the non-linear impact of rainfall is not clear enough. Families of the first group suffer negative impacts of temperature and rainfall in rainy season while families of the second group get positive impacts.

Farms of small size gain higher net income than medium and large farms. This suggests that efficiency in terms of profit is better in families with small farming areas.

Value of marginal impact of temperature is -VND71,240/family/^{0}C (≈ -VND108.000/ha/^{0}C). Value of marginal impact of rainfall is -VND380/family/mm/month (≈ -VND580 /ha/mm/month). It is estimated that by the end of the century (2100), according to the scenario B2, damage to the agriculture will amount to VND3,000 billion.

As for policies, this research provides information and estimates of economic impacts of increases in average temperature and rainfall on economic development of Vietnam besides impacts of the sea level rise. Economic damage will be remarkable, visible and continuous in years to come. Thus, it is necessary to improve the public awareness of global damage caused by climate change, take measure to reduce emission of greenhouse gas that makes the global warming more serious, and apply appropriate ways of adaptation to climate change to each zone or province■

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