

Article

The Impact of Extreme Events and Climate Change on Agricultural and Fishery Enterprises in Central Vietnam

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Abstract: Vietnam is located in the tropical monsoon region and it often faces many types of extreme weather events, especially storms and droughts. In addition to the effect of climate change, extreme weather events have been becoming more complicated and difficult to predict, causing heavy losses to many areas and economic sectors of the country. These problems impose a great threat to the country to achieve its socio-economic targets and sustainable development goals. This study uses a Riparian approach integrated with two-stage Hsiao method using a panel dataset from 2000–2018 to examine the impact of extreme weather events and climate change on the output of agriculture and fishery enterprises in the Central and Central Highlands regions of Vietnam. Findings from the study indicate that extreme weather events and climate change have a negative impact on agriculture and fishery enterprises in the regions. Specifically, the model results show that the value-added loss to agriculture and fishery enterprises as the impact of extreme weather events and climate change may escalate from billion VND 3597.72 to 18,891.2 under different climate change scenarios. The results also indicate the impact of various factors regarding extreme weather events and climate change on the efficiency of enterprises in the study area. Findings from this study provide insights on the impacts of extreme weather events and climate change on value-added of enterprises in the study regions and help to propose appropriate solutions to adapt and mitigate their impacts in the future.

Keywords: extreme weather events; climate change; agriculture; central regions of Vietnam; Ricardian model



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1. Introduction

Vietnam is located in the tropical monsoon region and often suffers with many types of extreme weather events. The problem is predicted to increase since Vietnam is one of the five countries most seriously affected by climate change [1]. According to the plan for implementation of the national strategy of prevention, control and mitigation of extreme weather events to 2020 (Plan for implementing the National Strategy for Prevention, Control and Mitigate the Impacts of Natural Disasters to 2020.), annual losses caused by extreme weather events can occupy about 1.5% GDP, and the magnitude of loss is increasing in terms of frequency and intensification. These factors will impose negative impacts to various economic sectors and the sustainable development of the country in the future. Agriculture is one of the sectors most seriously and continuously affected by extreme weather events and climate change [2–5]. Extreme weather events and climate change also impose significant impacts on the rural environment, the balance of forest ecosystems, agriculture and fisheries production, leading to losses on national capital, productivity, profitability and employment [6–10]. Food security is also clearly threatened by climate change [8,11,12] to the instability of agricultural production leading to

changes in the markets, food prices and supplying infrastructure. The negative impacts of extreme weather events and climate change on agriculture also fluctuate due to changes in temperature, precipitation, and the emergence of new forms of natural hazards [13].

As located in the tropical region, Vietnam has its competitive advantages in developing tropical agriculture with diverse ecological conditions, wide ranges of sunshine hours, and relatively rich water resources. Therefore, Vietnam's agricultural sector developed and obtained an average growth of 3.5% per year for the period of 1986–2018 (Calculated by the authors from statistic data). In combination with the population growth, domestic demand for grains and foods has increased remarkably while many agricultural and aquatic products have potentials and advantageous for export to the international market. However, with a narrow land strip area associated with a coastline extending from North to South, Vietnam has become one of the countries most heavily affected by extreme weather events and climate change in which storms and droughts are two types with the most serious impacts [14].

In Vietnam, agricultural production depends largely on weather. The increase of the temperature or the unusual fluctuations of the weather and climate change all affect agricultural production activities even seriously. The irregularities of climate cycle not only lead to an increase of diseases, pests and a decrease in crop yields, but also pose other serious risks. The Central and Central Highlands regions of Vietnam are the regions most heavily affected by extreme weather events and are most vulnerable to extreme weather events and climate change. These issues significantly affect the lives of farmers and business activities of enterprises in the regions, especially to agricultural production activities.

The aim of this study is to examine the impact of extreme weather events and climate change on the value-added of agriculture and fishery enterprises in the Central and Central Highlands regions of Vietnam in the period 2000–2018. Findings from this study may provide helpful hints to policy makers to draw appropriate solutions to adapt and mitigate the impacts of extreme weather events and climate change to the regions in the future. The remainder of this paper is organized as follows: Section 2 provides some related literature review of the study; Section 3 explains the application of the Ricardian model of the Hsiao two-stage approach using panel data for measuring the impact of extreme weather events and climate change. In Section 4, an econometrics model will be constructed, and the experimental study results will be presented. The paper ends with some conclusions in Section 5.

2. Literature Review

Economic studies have proposed various models that can be applied to assess the impact of extreme weather events, climate change on agricultural production activities. Of those, two mainstreams of economic models to assess the impact of extreme weather events, climate change include partial equilibrium models and general equilibrium models. Partial equilibrium models used in studies of economic impacts of extreme weather events, climate change are divided into two analytical directions. First, it is based on crop growth simulation models [15–17]. Second, micro econometric models such as the production function approach model [18–20] or the Ricardian model [21–24] are used.

Meanwhile, some studies show that all approaches above are focused on the agricultural sector with certain aspects such as farming activities or fisheries without considering its correlation with other economic sectors. Put differently, they are mostly focusing on partial equilibrium models. Therefore, several studies have been done to develop general equilibrium models (GEM) [25,26] to draw a more generalized understanding on the impact of extreme weather events, climate change in the simultaneous correlation of many sectors and areas [27–29]. The biggest limitation of the general model is the difficulty in collecting data relating market prices; therefore, it may influence the accuracy of models. Besides, a number of studies applied Geographic Information System (GIS) or satellite estimates to locate damage areas to assess the impact of natural hazards [30–34]. GIS may

become a good solution in incorporating the complexities of the spatial dimension within the analyses of climate change and adaptation.

Each type of models is with pros and cons, reflecting various complexities depending on the characteristics and specific contexts. Partial equilibrium models, with the Ricardian model in particular, are often chosen to assess the impact of extreme weather events, climate change in a certain market while general equilibrium models are commonly applied for research problems of total market. Regarding the Ricardian approach, models are mainly used to examine the impact of climate change on agricultural production using cross-section data within a certain year. However, the application of the Ricardian approach for the form of cross-section data by various years may result in unstable outcomes overtime [2]. To solve the limitation, recent studies use time-series data instead of using cross-section data to calibrate in the Ricardian models [2,35]. Thus, analysis of various climatic periods may offer a more exact means of measurement toward climate change issues.

Two approaches of time-series data can be applied for a Ricardian model; they consist of the Hsiao two-stage model [36] and the “pooled” data model. The study by Hsiao (2008) produced a model with better ability of prediction. In Vietnam, the study by [37] has corrected the shortcomings of the Ricardian model by using the two-stage method of [36] with a time-series data from a Vietnam Household Living Standard Survey of the General Statistic Office. The results show heterogeneous impacts for different regions and negative effects of higher temperatures for all regions. Moreover, to examine the potential interaction impact between temperature and precipitation as well as climate change factors by regions, [37] complements interaction variables of temperature and precipitation into the model.

Nevertheless, although the Ricardian model has been applied with cross-section or panel data, most studies focus on examining the impact of climate change on farm households with direct participation in the process of production, while another important component of the economy, that is agricultural production or fishery enterprises, that have been continuously suffering from the impact of climatic variation and climate change factors, has not been much investigated [38,39]. Thus, this study aims at achieving the following two main objectives: (i) assessing the impact of extreme weather events (i.e., storms and droughts) and climate change on the value of outputs of agriculture and fishery enterprises in the Central and Central Highlands of Vietnam in the period 2000–2018 using a riparian approach with panel data; and (ii) estimating the losses and benefits to enterprises under various climate change scenarios.

3. Methodology

3.1. Output Measurements of Enterprises

This study uses the indicator of value-added to reflect the output of the enterprises where value-added (VA) is measured by the value of gross outputs minus intermediate, the cost of intermediate inputs. The efficiency of an enterprise is not only depending on the ability to generate the greatest revenue, but also on the ability to save costs of intermediate inputs. Therefore, this indicator accurately reflects the efficiency and is often used in studies on measuring and assessing the efficiency of the enterprises. Unfortunately, production cost data is not available in the dataset. Thus, according to General Statistics Office of Vietnam (GSO), value-added is defined as the sum of labor compensation and capital rent payment. In this study, VA will be measured based on the factor income approach, which determines the income of labor and capital separately. Capital income is defined as the sum of depreciation cost and total profit of enterprise.

3.2. Ricardian Model Selection Using Panel Data to Measure the Impact of Climate Change

Original Ricardian method assumes the value of production generated from agricultural land (V) is equal to present value of net revenue from farming activities [21]. Thus, the value of land can be described as follows:

$$V = \int [\sum PQ(I,C,G,S) - R' I] e^{-\delta t} dt \quad (1)$$

where: V is net revenue per hectare of land; P is market price of the output; Q is the output; I is a vector of purchased inputs (except land); C is a vector of climate change; G is a vector of geographic location; S is a vector of variables regarding the land; R is a vector of prices of the inputs; t is time, and δ is discount rate. Farmers are assumed to maximize their revenue by choosing I with climate, soil, geographic variables, market prices and other exogenous socio-economic conditions.

Solving (1) to maximize net revenue leads to a model where V is a function of exogenous variables facing the farmer: S, G, C, R, r , and Z .

From the underpinnings of the Ricardian approach in assessing the impact of climate change on the income of farmers, this study examines the impacts on the outputs of agriculture and fishery enterprises. The study applies panel with a number of variables including: a vector of time variable, X ; a vector of invariant time variables, Z ; a vector of extreme weather events (storms, droughts), and climate change (temperature and precipitation). Time variables consist of capital intensity, human capital, ratio of external capital, and enterprise scale. Time invariant variables consist of sector and geographic factors. The Ricardian model can be described as follows:

$$V = f(X, Z, C) \quad (2)$$

Reference [2] states that in models with cross-section data, the coefficients do not vary over time and in ideal models with panel data, coefficients of time invariant variables also do not vary. Therefore, the Ricardian model determined will be:

$$V_{i,t} = \beta \times X'_{i,t} + \gamma \times Z'_I + \varphi \times C'_I + u_{i,t} \quad (3)$$

where: $X_{i,t}$ is a matrix of time variant target variables. Estimated coefficients are all the matrix. β, γ and φ are time invariant vectors. By allowing β and γ to be variable over time, the looped cross-sections causing φ will also be variable.

This study applies the most efficient approach—Hsiao's two-stage approach—to evaluate the impacts of extreme weather events and climate change on enterprise's output: The first stage of Hsiao's approach is to control variables with correlation in respect to location factor using the method of fixed effects with the dependent as logarithm of value-added and independent variables to be variable over time, including the variables of the characteristics of the enterprises and time variables; in the second stage, mean residuals regressed from the first stage will become a dependent variable in the model of evaluating the impacts of independent variables reflecting the characteristics of extreme weather events and climate change.

In the first stage, to test the consistency of the coefficients in relation to climate factors over time, this study uses the estimation with panel data:

$$V_{i,t} = \beta \times X'_{i,t} + e\alpha_i + \varepsilon_{i,t} \quad (4)$$

where: e is a vector of fixed effects in respect to location (province), and ε_i, t are error terms. By including fixed effects, the first stage in Hsiao model is undertaken to control missing variables with better location correlation. In the second stage, mean errors in respect to time are regressed over time-invariant variables using WLS method:

$$\bar{V}_i - \bar{X}'_i \hat{\beta} = e\alpha_i + \varepsilon_i = \gamma \times Z'_i + \varphi \times C'_i + u_i \quad (5)$$

In the second period, the study estimates a specific coefficient, φ_t :

$$\bar{V}_{it} - \bar{X}'_{it} \hat{\beta} = \gamma \times Z'_i + \varphi_t \times C'_i + u_{i,t} \quad (6)$$

This model is equivalent to generating a set of time dummy variables for each year and taking interaction variables between these dummy variables and climate variables.

The impact on the welfare, W of extreme weather events, and climate change in respect to each of the three regions and to each of the two sectors is calculated by considering the difference between the outputs by new climate scenarios (C_1) and the outputs of the enterprises in the current climate conditions (C_0) with the scale of agriculture and fishery enterprises as the weight (F). This study uses predicted coefficients of mean outputs and the change of climate forecasts from C_0 to C_1 :

$$W = \sum_i [V_{it}(C_1) - V_{it}(C_0)] F_i \quad (7)$$

3.3. Data Collection

To examine the impact of extreme weather events and climate change on the output of agriculture and fishery enterprises in the Central and Central Highlands regions, this study uses annual survey data of the GSO from 2000 to 2018 (the latest survey available) and meteorological dataset from the Central Center of Metrology and Hydrology in 8 provinces of the Central and Central Highlands regions, including: Nghe An, Thua Thien Hue, Da Nang, Binh Dinh, Gia Lai, Lam Dong, Khanh Hoa, and Binh Thuan. The survey, starting in 2000, covers the information enterprise (taxation code), employment, nominal physical capital, costs of intermediate goods (materials and other services), investment, annual sales, and other information on wage, debts, social security, and so on. The survey database is quite suitable for study paper at the firm level. For the purpose of this study, only enterprises in the agriculture and fishery industry with positive capital, labor and value-added are kept in a database. The dataset completed is an imbalance panel data with 13,363 observations in 19 years from 2000 to 2018. Variables in monetary values are adjusted for various years using annual inflation rates.

Meteorological data of 12 months in years are not used in this study because there is a multi-collinearity problem between monthly precipitation and temperature. Instead, the authors calculate and use the precipitation and temperature by seasons as following the seasonal classification by the Ministry of Natural Resources and Environment [40].

3.4. Proposal of an Experimental Model

Based on the Ricardian approach with panel data to apply for agriculture and fishery enterprises in the Central and Central Highlands regions of Vietnam, this study establishes a model to examine the impact of extreme weather events and climate change on value-added of the enterprises. The model is shown as below:

$$\ln VA_{it} = \alpha + \beta \text{characteristic}_{ijt} + \delta_1 \text{extr_weath}_{ij} + \delta_2 \text{extr_weath}2_{ij} + \varphi_1 \text{climate}_{ij} + \varphi_2 \text{climate}2_i + \text{interact}_i + u_{it} \quad (8)$$

where:

- it : enterprise i and in the year t .
- $\ln VA_{it}$: logarithm of value-added of enterprise i in the year t (%).
- $\text{characteristic}_{ijt}$: vector describing specific characteristics of enterprise, including capital intensity (KL), human capital (LC), proportion of external capital (vng), enterprise scale ($scale$).
- extr_weath_{it} : vector describing variables relating to extreme weather events at the location of enterprise i in the year t (including variables of $storm$ and $drought$).
- $\text{extr_weath}2_{it} = \text{extr_weath}d_{it} \times \text{extr_weath}_{it}$
- climate_{it} 1: vector describing variables relating to climate change at the location of enterprise i in the year t , (including temperature and precipitation), of which, each

variable of *temp* or *prec* is separated into two variables in equivalent to the temperature and precipitation of Spring–Winter season, Summer–Autumn season.

- $climate2_{it} = climate_{it} \times climate_{it}$
- u_{it} : measurement error and is considered as the impact of efficiency shocks and is assumed with independent distribution. To deal with errors in regression using cross-section data and to examine the impact of extreme weather events and climate change in a relatively long period of time to increase the accuracy and the appropriate of the model, this study undertakes regression with panel data.
- Details of variable names are described in Table 1 below.

Reference [35] assert that the regression with the repeating of the variables of extreme weather events and climate will lead to inconsistent estimates. In fact, climate change is a long process with a timeframe of 20–30 years. Estimates of different impacts of climate change over different years may not generate a proper correlation. Hsiao's two-step method allows an estimation of invariant variables over time and provides sound estimates of climate impacts. Therefore, the study uses Hsiao's two-step approach to estimate the impact of extreme weather events and climate change with panel data. The use of enterprise's asset size as a weighting, in stage 2, can help to adjust for the change of variance that is considered a particular problem in econometric models.

3.5. Variable Descriptions of the Model

Table 1 shows the key variables descriptions in the model in the period 2000–2018. Variables in monetary values are adjusted for inflation. To evaluate the impact of climate change by sectors and regions, the research uses interaction variables between climate change and sector, region (*climate_north*, *climate_south*, *tem10_agri*, *tem35_agri*). Particularly, the potential interactions between temperature and precipitation by seasons are also examined in the model (*prec_temp_WS*, *prec_temp_SA*).

Table 1. Key variables descriptions to be examined in the model.

| Variable | Measurement |
|--|---|
| Capital (K) | Real capital input, measured by total fixed assets—depreciation (Mil. VND) |
| Labor (L) | Labor input, measured by average number of enterprise employees in the year (Persons) |
| <i>Dependent variable</i> | |
| Value-Added (VA) | Value-Added of enterprise, and this variable is given in the model under the form of logarithm (lnVA). |
| <i>Variables reflecting enterprise characteristics (characteristics)</i> | |
| KL | Capital intensity, measured by capital stock per worker (Mil. VND per person) |
| LC | Human capital, measured by total wages and training costs per worker (Mil. VND per person) |
| vng | Proportion of external capital stock, measured by 1—equity/total asset |
| scale | Enterprise scale, taking the value of 1 if enterprise is micro-sized enterprise (less than 10 labors); of 2 if small-sized enterprise (greater than 10 but less than 100 labors); of 3 if medium-sized enterprises (greater than 100 but less than 200 labors) and of 4 if large-sized enterprises (over 200 labors). |
| <i>Variables reflecting extreme weather events (extr_weath)</i> | |
| storm | Mean of storm level (grade) |
| drought | Drought index by Selianninov (monthly mean) |
| extr_weath2 | Taking square of specific variables of extreme weather events (<i>storm2</i> , <i>drought2</i>) |
| <i>Variables reflecting climate change (climate)</i> | |
| prec_WS | Monthly mean value of precipitation of Winter–Spring season from October to March of the next year (mm) |
| prec_SA | Monthly mean value of precipitation of Summer–Autumn season from April to September of the year (mm) |
| temp_WS | Monthly mean value of temperature in Winter–Spring season (°C) |
| temp_SA | Monthly mean value of temperature in Summer–Autumn season (°C) |
| climate2 | Taking square of climate change variables (<i>including:prec_WS2</i> , <i>prec_SA2</i> , <i>temp_WS2</i> , <i>temp_SA2</i>) |
| temp10 | Number of days with the temperature below 10 °C by provinces |
| temp35 | Number of days with the temperature over 35 °C by provinces |
| <i>Regional dummy variables (Region)</i> | |
| north | Dummy variable taking the value of 1 if the enterprise is located in Vietnam's Northern Central region and taking value of 0 if otherwise. |
| south | Dummy variable taking the value of 1 if the enterprise is located in Vietnam's Southern Central region and taking value of 0 if otherwise. |
| <i>Sector dummy variables (Sector)</i> | |
| agri | Dummy variable taking the value of 1 if the enterprise is specialized in agricultural production and taking value of 0 if otherwise. |

Table 1. Cont.

| Variable | Measurement |
|------------------------------|--|
| <i>Interaction variables</i> | |
| <i>prec_temp_WS</i> | The product between the means of precipitation (<i>prec</i>) and temperature (<i>temp</i>) of Winter-Spring season |
| <i>prec_temp_SA</i> | The product between the means of precipitation (<i>prec</i>) and temperature (<i>temp</i>) of Summer-Autumn season |
| <i>climate_north</i> | The product between the characteristic variable of climate (annual mean) and dummy variable <i>north</i> (including: <i>prec_north</i> , <i>temp_north</i>) |
| <i>climate_south</i> | The product between the characteristic variable of climate (annual mean) and dummy variable <i>south</i> (including: <i>prec_south</i> , <i>temp_south</i>) |
| <i>tem10_agri</i> | The product between the variable <i>tem10</i> and variable <i>agri</i> |
| <i>tem35_agri</i> | The product between the variable <i>tem35</i> and variable <i>agri</i> |
| Time dummy variable | 2001 year; 2012 year . . . to 2018 year |

Source: Summarized by the authors.

3.6. Statistical Description of the Variables

Table 2 shows statistical descriptions of key variables in the period 2000–2018. The average number of labors of agriculture and fishery enterprises in the Central and Central Highlands regions is about 55, of which, the labors mostly focus in the agricultural sector with a mean of 75 labors per enterprise while in the fisheries, the value is only at 26 labors per enterprise. The number of labors is with an increasing trend over time in respect to an increase of the number of enterprises.

Table 2. Mean statistical descriptions of key variables in the period 2000–2018.

| Variable | Mean | Variable | Mean | Variable | Mean |
|-----------------------------|-----------|--------------|--------|--------------|--------|
| Labor (L) (person) | 55 | prec_WS (mm) | 97.67 | temp_WS (°C) | 23.41 |
| Capital (K) (Mil. VND) | 12,923.45 | prec_SA (mm) | 244.15 | temp_SA (°C) | 27.753 |
| Value-Added (VA) (Mil. VND) | 1204.32 | storm (cap) | 7.8 | drought | 2.135 |

Source: Calculated by the authors from GSO data.

The average value of capital stock of enterprises is Mil. VND 12,923 per enterprise. The capital stock invested in agriculture is 5 times higher than that invested in fisheries. The statistic results also show that value-added of enterprises in the Central and Central Highlands in the period of 2000–2019 is about Mil. VND 1204.32 per year with inconsistent variability over years. At the end of period, from 2016 to 2018, the number of enterprises increases, but the value-added is with a decrease trend. Regarding variables reflecting climate change, the precipitation in autumn season and the temperature in the summer season are highest with 312.582 mm and 27.162 °C, respectively.

4. Results and Discussions

Based on the Ricardian approach using panel data to examine the impact of extreme weather events and climate change on value-added of agriculture and fishery enterprises in the study regions, the results are given in the following sections.

4.1. Impact of Enterprise's Characteristic Variables on the Value-Added

Table 3 shows estimated results based on Hsiao approach for control variables over time while Table 4 presents the results estimated for climatic variables and invariant control variables over time. The purpose of integrating dummy variables relating to time into the model is to control unobservable factors by years that may influence the outputs of the enterprises. The level of interpretation of the model reflected by R^2 was 78.7%, more than the studies by [37] as 58%, [41] as 53%, quite similar to the study by [35] as 80%. Therefore, a large part of the variation in enterprise's value-added is explained by the independent variables.

The results of model test indicate that the model does not violate the assumptions of an OLS regression relating to the problems of multi-collinearity, autocorrelation, or heteroscedasticity. The estimated results for two models with the dependent variable of

lnVA show that there are almost no differences between the impact factors of time control variables in the models; however, there are large differences between the intensity of the impacts.

Among the variables of enterprise characteristics, the coefficient of the average income variable takes the positive sign and with a high level of statistical significance in the model (2). An increase in *LC*, representing the average income, would encourage the workers to increase the productivity, and then, the efficiency of the enterprises. The coefficients of *KL* and *vng* are both with positive signs, of which, the *vng* is with statistical significance, indicate that the level of current capital investment of enterprises in the Central and Central Highlands regions in the agricultural and fisheries sectors is appropriate with capital structures from outside stakeholders that has been positively influencing and increasing the value-added of enterprises. Large-scale enterprises tend to be more efficient than small-scale enterprises. Large-scale enterprises with applying advanced technology and developing actively solutions to effectively respond to the impacts of climate change tend to improve enterprise's value-added. The result contrasts with the analysis by [42,43] in farmer's production which show that the small-holding farmers tend to be more productive than large-holding farmers.

Table 3. Coefficients of time variant variables in the Hsiao model.

| | (1) | | (1) |
|-----------|--|--------------|-----------------------|
| Variables | <i>lnVA_Stage 1</i> | Variables | <i>lnVA_Stage1</i> |
| LC | 0.000830 *** (0,000318) | 9. year | 0.452 *** (0.0497) |
| KL | 7.93×10^{-6} (8.95×10^{-6}) | 10. year | 0.401 *** (0.0511) |
| vng | 0.00168 * (0.000998) | 11. year | 0.216 *** (0.0531) |
| scale | 0.765 *** (0.0275) | 12. year | 0.458 *** (0.0542) |
| 1.year | 0.148 *** (0.0213) | 13. year | 0.480 *** (0.0572) |
| 2.year | 0.196 *** (0.0263) | 14. year | 0.338 *** (0.0541) |
| 3.year | 0.137 *** (0.0423) | 15. year | 0.309 *** (0.0547) |
| 4.year | 0.144 *** (0.0485) | 16. year | 0.370 *** (0.0566) |
| 5.year | 0.116 ** (0.0521) | 17. year | 0.595 *** (0.0563) |
| 6.year | −0.0794 (0.0527) | 18. year | −0.0480 (0.0746) |
| 7.year | 0.293 *** (0.0518) | Intercept | 3.339 *** (0.0619) |
| 8.year | 0.260 *** (0.0497) | Observations | 13.363 |
| | VIF | | 2.33 |
| | Modified Wald Test | | 4435.45 *** |
| | Wooldridge test | | 136.856 *** |

Standard errors in parentheses, *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Source: Calculated by the authors with the data from GSO.

The coefficients regarding time control variables for various years are all with statistical significance and taking positive signs (except for the years of 2006 and 2018). The lift of barriers relating to rice exports and the government policies to support agricultural production have been contributing to an increase of a value-added of 0.452% in 2009, and remaining at the level of 0.338–0.458% from 2012 to 2014. In 2017, a number of policies

to encourage and support agriculture and fishery enterprises began to take effect as well as favorable economic development, making the value-added of enterprises increased by 0.595%.

The results above may reflect the socio-economic development context of Vietnam. To ensure sustainable economic growth and environmental protection in response to extreme weather events and climate change, over the last decade, the Vietnamese Government has issued various strategies and policies. Some examples in this regard can be given such as the National Target Program to Respond to Climate Change (2008); the National Strategy on Climate Change (2011); the Law on Natural Disaster Prevention and Control (2013); the Action Plan to respond to climate change in agriculture and rural development (2016). In addition, changes in the macro-economic environment that were integrated in the national program and strategy on climate change in the period 2000–2018 are found to have an important role to promote and increase the enterprises' value-added.

Table 4. Coefficients of invariant variables in the Hsiao model.

| | (2) | | (2) |
|----------------|----------------------------|--------------|---|
| Variable | lnVA_Stage2 | Variable | lnVA_Stage2 |
| storm | −3.252 *** (1.086) | storm2 | 0.232 *** (0.0693) |
| drought | −1.932 *** (0.389) | drought2 | 0.0374 *** (0.000140) |
| prec_WS | 0.0713 *** (0.00898) | prec_WS2 | $−4.99 \times 10^{-6}$ *** (9.01×10^{-7}) |
| prec_SA | 0.0103 ** (0.00423) | prec_SA2 | $−1.54 \times 10^{-6}$ *** (2.00×10^{-7}) |
| temp_WS | 6.697 *** (0.698) | temp_WS 2 | −0.0821 *** (0.0117) |
| temp_SA | −8.356 *** (0.745) | temp_SA2 | 0.045 *** (0.00161) |
| temp_north | 0.145 *** (0.0273) | prec_agri | −0.000682 *** (0.000190) |
| temp_south | 0.197 *** (0.0333) | temp_agri | 0.163 *** (0.0142) |
| prec_north | −0.0268 *** (0.00204) | drought_agri | −0.320 *** (0.0102) |
| prec_south | −0.0303 *** (0.00424) | temp10_agri | −0.0575 *** (0.00667) |
| prec_temp_WS | −0.00047 *** (0.00013) | temp35_agri | −0.0450 *** (0.000348) |
| prec_temp_SA | −0.00271 *** (0.000348) | Intercept | 0.298 (5.037) |
| R ² | 0.787 | | |

Standard errors in parentheses; *** $p < 0.01$, ** $p < 0.05$. Source: Calculated by the authors with the data from GSO.

4.2. Impact of Extreme Weather Events and Climate Change on the Output of Enterprises

The estimation results in Table 4 show that all variables are statistically significant, except for the intercept.

According to the estimation results, in the Central Highlands, temperature has the most negative impact on the enterprises; however, precipitation is the factor that has the most positive impact on the enterprises, compared with the North Central and South Central regions (the coefficients of two interaction variables *temp_north* and *temp_south* both have positive signs with the magnitude of the effects greater than the two variables *prec_north* and *prec_south* with negative signs). The temperature in the Central Highlands has a rather strong fluctuation, although the heat base is lower than the other two regions, but it tends to increase significantly over time and all these have significantly influenced agricultural production activities.

In addition, the agricultural economy in the Central and Central Highlands provinces is mainly food production, although these regions do not have advantages in such activities. Moreover, with unusual factors of extreme weather events and climate change that are rapidly occurring, storms, floods, and droughts make agricultural production heavily affected by extreme weather events and climate rather than aquaculture and fishing activities (most of the variables interacting with the variable *agri* have negative relationships). The efficiency of agricultural production in the Central and Central Highlands regions is therefore also lower than that of fisheries.

Specific analysis of each type of extreme weather events and climate change provides a clear view of the impacts of extreme weather events and climate change on agriculture and fishery enterprises.

4.3. Impact of Extreme Weather Events

Table 4 indicates that the group of variables representing extreme weather events shows that the storm-specific variable *storm* has a negative relationship and is statistically significant at 1%. This indicates that an increase of *storm* at 1 unit will cause a decrease of 1.44% in the value-added of agriculture and fishery enterprises in the Central and Central Highlands regions, assuming other variables are kept unchanged. The number of strong storms tends to increase, in terms of quantity and intensity. The storm season tends to end later and the trajectory of storms becomes abnormal, affecting agricultural production activities of enterprises. Especially, the occurrence of more super storms has caused heavy loss to fishing activities on the sea, destroyed aquaculture production, and damaged dyke systems and crops. These effects are very serious because enterprises often have a large production scale. With strong storms, in addition to poor weather forecasts and the limited ability to cope, the loss will be obvious.

The variable *drought* also shows a negative and clear impact on the efficiency of enterprises, with higher intensity than variable *storm*. An increase of the index at 1 unit will cause a decrease of 1.85% in the value-added of the enterprises. Although regions are affected by droughts, the drought level in the Central region and the Central Highlands is more serious than in other regions of the country. Droughts tend to expand, especially in the Central Highlands and South Central Coast, leading to an increase in desertification and a decrease in cultivated area.

Irrigation systems in the Central Highlands were planned and built to supply water for agricultural production under normal conditions. However, in the context of climate change in combination with the deterioration of many irrigations works, irrigation assurance sometimes faces critical problems. Specifically, the irrigation systems of the whole region were designed to supply for 214,645 ha; however, the actual irrigated area is only occupying 74.4% of the design capacity. The irrigation systems only meet 30% of the total area as required for the region.

In recent years, due to complicated climate and unusual weather changes with prolonged hot weather, water quantity for irrigation is declining, even groundwater source is also seriously decreased. High temperature base leads to water shortages in dry season and threaten forest fires, especially in Gia Lai. Therefore, in the dry season, tens of thousands of cropping hectares such as coffee, pepper, wet rice, and short-term crops in the Central Highlands lack irrigation water seriously which badly affects the yield and productivity of agricultural enterprises.

When considering the effect of the variable *drought* by type of enterprises, the model results show that the impact of droughts causes higher loss to the agricultural enterprises in comparison to the loss to the fishery. Regarding the production scale of enterprises, the cultivated area is often much larger than that of aquaculture with the main crops of rice, tea and some fruit trees that require a large amount of water for irrigation. If the drought lasts for long in combination with little precipitation, the growth and development of the crops will be seriously affected. In the Central region, freshwater and saltwater aquaculture has

been well developed and droughts do not much affect the outputs of fishery enterprises in comparison to the temperature factor.

4.4. Impact of Climate Change

To assess the impact of climate change more accurately, this study divides factors of climate change by two seasons, winter-spring and summer-autumn, with two types of different climatic and weather variables including precipitation and temperature [44]. Estimated results show that most of the variables reflecting climate change are statistically significant. The trend of change in temperature and precipitation in the study are also quite similar to the one found by the studies of [45,46]. The results show that the precipitation, when considered separately, has a positive effect on the output of enterprises in both models. Specifically, when the winter-spring and summer-autumn precipitation increases by an average of 10 mm, the value-added of the enterprises increases 0.81%. In combination with the negative sign of the *drought* variable, it indicates that the problem of water shortage is occurring in the Central and Central Highlands regions. An increase of precipitation will help solve the problem of drought in the area and positively affect agricultural production. However, the impact of precipitation on the efficiency of enterprises is not as high compared to the effect of the temperature factor. For the whole year, the annual precipitation has a positive impact on value-added of enterprises.

Regarding the effect of temperature factor, the model shows that the impact trend of temperature to enterprise's value-added is dependent on seasons, similar to the findings of [45,47]. Summer-autumn temperature had a negative impact on the value-added of enterprises while winter-spring temperature had a positive effect. Summer and autumn are two seasons with the highest heat of the year. Hot weather often lasts for long and leads to water shortage, droughts, an increasing precipitation, and further results in other extreme weather events such as storm, floods, and landslides [48], therefore, it negatively influences the production activities of enterprises. The model results indicate that an increase in 1 °C of the summer-autumn temperature leads to a decrease of 7.26% in the value-added of the enterprises. Hot weather affects the growth of crops and causes disease risks, leading to an increase in production costs and a decrease in productivity.

On the contrary, the model shows a positive impact of the winter-spring temperature on the value-added of the enterprises. The increase of the temperature in regions with warmer winters favors the growth of rice and other crops, helping increase the fruiting rate in fruit growing areas, especially in the South Central region. However, extreme temperature events also have strong impacts on enterprise performance. Extreme climatic factors such as too high temperatures (variable *temp35*) and too low temperatures (variable *temp10*) affect agricultural production greater than aquaculture. A change in temperature of the whole year still has an enormous negative impact on the efficiency of enterprises in the Central Region and Central Highlands regions.

Combining both temperature and precipitation factors into the model, it shows a clearer impact of climate change on the enterprises. Although both winter-spring and summer-autumn precipitation have positive impacts on agriculture and aquaculture, there is a large interdependence between the temperature and precipitation factors if the temperature is included in the model. The model results show that the effect of temperature also depends on the precipitation in two seasons. The estimates of the interaction variables between precipitation and temperature in the two seasons are statistically significant. When the winter-spring crops begin, higher temperature will have a negative impact if there is a lack of rainfall. In particular, an increase in temperature in summer and autumn has a negative effect on the growth of crops and leading to higher irrigation costs due to evaporation. With summer-autumn crops, an increase in temperature will negatively affect production activities. When the average temperature is below 27.75 °C, the precipitation needs to be more than 244.15 mm to minimize the negative impact of the temperature. This analysis is consistent with the results by [37].

Considering the impact of climate change by regions, it can be seen that the temperature in the North Central and South Central regions provides a good signal for agricultural and fishery production activities compared to the Central Highlands region (two interaction variables *temp_north* and *temp_south* are both with positive signs). The results are similar to the findings of [49]. In particular, the temperature in the North Central region has a higher impact on production than that in the South Central region. Considering the precipitation factor, the precipitation in the North Central and South Central regions has a larger negative impact on production than that in the Central Highlands region. This is the region that is receiving the support from many programs to agricultural and fishery production activities. Some provinces are favorable with natural conditions for the development of agricultural production, especially in Lam Dong province with a cool climate, higher precipitation than other areas of the country. In Phu Yen province, in addition, aquaculture and capture fisheries are also favorable for development, with only few storms and floods occurring in this area. However, because the areas are located in the highlands with many mountainous forests, drought and deforestation problems are greater than other regions and the precipitation factor plays an important role in the Central Highlands. To improve the efficiency of agricultural and aquaculture enterprises, the Central Highlands region need to pay special attention to improving the quality of irrigation systems to solve the problems of droughts to affect production activities.

The main influence of climate change in the Central and the Central Highlands regions is the anomalies of climate change in the general base of increasing temperature that will have more serious effects if the problem of water shortage in the dry season exists, especially in the Central Highlands. The mountainous areas in the North Central region with increasing heat base in combination with droughts can lead to forest fires, while in the South Central region, the problem of desertification increases.

4.5. Estimation of the Losses Caused by Climate Change to Agriculture and Fishery Enterprises in Central and Central Highlands Regions

To understand about the impact of climate change, this study simulated the impact of future climate change on agricultural and fishery outputs of the enterprises in the Central and Central Highlands regions from the Ricardian model results. Scenarios used in this study are climate change scenarios PCP 4.5 and PCP 8.5 with respect to three periods of 2035, 2065 and 2099 that are described in detail in [40]. The variation in temperature and precipitation differ among seasons and regions. The temperature is expected to increase from 0.7 °C to 3.7 °C between 2035 and 2099. The temperature in summer and autumn is predicted to increase faster than that in the spring and winter seasons. The temperature in the North-Central and the Central Highlands regions will increase faster than that in the South Central region. Average precipitation in the Central region is forecast to increase but with different patterns for the seasons. The number of storm days in general does not change much according to the climate change scenarios (i.e., from 11.71 to 11.78 days) while the magnitude of the storms will increase by 2 to 11%. Thus, the simulation of the impact of the climate change factors over time and space may provide insights to recommend right solutions to the problem.

Since all the coefficients in the Ricardian model were estimated at the mean value of the sample, in this study the difference between the expected climate and the sample mean was calculated for each region and each season. The differences were then multiplied by the corresponding coefficients from Step 2 of the Hsiao estimation results. The impact of climate change for each region and season was calculated using the size of assets for each region as a weight. The estimated impact of changes in temperature or precipitation on a given region was obtained by aggregating the seasons. The impact of climate change by seasons was aggregated across regions. The total impact of seasonal climate change is the total impact of temperature and precipitation, number of storm days, and storm magnitude. The positive effects of increased precipitation in some regions are overwhelmed by the negative effects of temperature changes over a long period of time. Therefore, the aggregate impact of climate change is negative across regions and sectors.

The estimates of the output losses for each climate change scenario PCP 4.5 and PCP 8.5 through 2035, 2065 and 2099 are shown in the Table 5 below.

The estimated results of losses by regions show that Central Highlands is the region most affected by the temperature factor (decrease of billion VND 1843 to 4764 under Scenario 4.5); however, it is also the region that benefits most from the change of the precipitation in comparison to the other remaining regions (from billion VND 822.2 to 1477.95 under Scenario 4.5). The trend of climate change has a more negative impact on the Central Highlands region until 2099. The Central Highlands is a region with a large area of agricultural production compared to the other two remaining regions and the size of enterprise assets is also largest, so total loss will be highest compared to the others because droughts and hot climate tend to increase in this region. The South Central is a region least impacted by the temperature factor (with a decrease of billion VND 1091.91 to 2700.37 under Scenario 4.5); however, it also benefits least from the precipitation factor (with an increase from billion VND 72.63 to 277.26 under Scenario 4.5).

Table 5. Estimation of output losses as effects of extreme weather events and climate change by various scenarios (Bil. VND).

| Indicator | 2022–2035 | | 2046–2065 | | 2080–2099 | |
|--------------------------|-----------------|-----------------|-----------------|-------------------|------------------|-------------------|
| | PCP4.5 | PCP8.5 | PCP4.5 | PCP8.5 | PCP4.5 | PCP8.5 |
| Central Highlands | | | | | | |
| Storm | −57.92 | −73.72 | −68.45 | −84.25 | −78.98 | −94.78 |
| Drought | −291.11 | −370.50 | −344.04 | −423.43 | −396.96 | −476.36 |
| Precipitation | 822.20 | 955.53 | 1472.44 | 450.84 | 1477.95 | 1457.38 |
| Temperature | −2316.86 | −2613.26 | −4824.05 | −5955.39 | −5766.79 | −9676.86 |
| Central Highlands | −1843.68 | −2101.94 | −3764.10 | −6012.23 | −4764.79 | −8790.62 |
| South Central | | | | | | |
| Storm | −86.64 | −110.27 | −102.39 | −126.02 | −118.14 | −141.77 |
| Drought | −127.00 | −161.64 | −150.09 | −184.73 | −173.18 | −207.82 |
| Precipitation | 72.63 | 73.79 | 334.52 | 321.42 | 277.26 | 293.85 |
| Temperature | −1091.91 | −1225.47 | −2274.62 | −2796.69 | −2700.37 | −4521.90 |
| South Central | −1232.92 | −1423.58 | −2192.58 | −2786.02 | −2714.44 | −4577.64 |
| North Central | | | | | | |
| Storm | −226.31 | −288.03 | −267.46 | −329.18 | −308.61 | −370.33 |
| Drought | −118.48 | −150.79 | −140.02 | −172.34 | −161.57 | −193.88 |
| Precipitation | 145.75 | 157.12 | 497.20 | 337.39 | 431.46 | 449.09 |
| Temperature | −1322.08 | −1473.13 | −2756.05 | −3368.82 | −3239.25 | −5407.83 |
| North Central | −1521.12 | −1754.84 | −2666.33 | −3532.95 | −3277.96 | −5522.95 |
| Agriculture | | | | | | |
| Storm | −314.19 | −399.87 | −371.31 | −457.00 | −428.44 | −514.12 |
| Drought | −461.01 | −586.74 | −544.83 | −670.56 | −628.65 | −754.38 |
| Precipitation | 920.13 | 1050.61 | 2008.45 | 132.66 | 1912.74 | 1922.21 |
| Temperature | −4059.41 | −4558.40 | −8456.00 | −10,401.33 | −10,046.20 | −16,826.65 |
| Agriculture | −3914.48 | −4494.41 | −7363.70 | −11,396.23 | −9190.55 | −16,172.94 |
| Fisheries | | | | | | |
| Storm | −56.69 | −72.14 | −66.99 | −82.45 | −77.30 | −92.76 |
| Drought | −75.58 | −96.19 | −89.32 | −109.93 | −103.06 | −123.67 |
| Precipitation | 120.45 | 135.83 | 295.72 | 75.32 | 273.93 | 278.12 |
| Temperature | −671.43 | −753.46 | −1398.72 | −1719.56 | −1660.21 | −2779.94 |
| Fisheries | −683.24 | −785.96 | −1259.31 | −1836.62 | −1566.64 | −2718.26 |
| Central Region | | | | | | |
| Storm | −370.9 | −472.0 | −438.3 | −539.4 | −505.7 | −606.9 |
| Drought | −536.6 | −682.9 | −634.2 | −780.5 | −731.7 | −878.1 |
| Precipitation | 1040.6 | 1186.4 | 2304.2 | 208.0 | 2186.7 | 2200.3 |
| prec_WS | 725.9 | 818.0 | 1843.3 | 22.3 | 1685.5 | 1718.7 |
| orec_SA | 314.6 | 368.5 | 460.9 | 185.7 | 501.2 | 481.6 |
| Temperature | −4730.8 | −5311.9 | −9854.7 | −12,120.9 | −11,706.4 | −19,606.6 |
| temp_WS | 5143.7 | 6434.7 | 10,594.7 | 14,256.9 | 14,602.5 | 25,465.1 |
| prec_SA | −9874.6 | −11,746.5 | −20,449.4 | −26,377.7 | −26,308.9 | −45,071.7 |
| Central region | −4597.72 | −5280.37 | −8623.01 | −13232.80 | −10757.19 | −18891.20 |

Source: Calculated by the authors from the simulated model.

In addition to the negative impact factors by weather phenomena and climate change, in some seasons, climate change may create positive impacts, helping improve the efficiency of agriculture and fishery enterprises in the Central region, although the intensity is weak. These factors comprise of temperature in spring and winter seasons of the entire Central region or precipitation in the summer and winter seasons in the Central Highlands. However, the aggregate impact of extreme weather events and climate change is negative on agriculture and fishery enterprises with the magnitude of the impact to increase over time.

In the Central region, agriculture is the main economic sector; therefore, the impact of extreme weather events and climate change on the agricultural sector is bigger in comparison to that on the fisheries. The loss of the agricultural sector is about billion VND 3914.48 to 16,172.94 under different climate change scenarios up to 2099, about 5 times higher than that of the fisheries sector. The agricultural land area with many times larger than that of aquaculture is also considered a reason to the much greater loss in agricultural production than in fishery.

5. Conclusions

Vietnam is forecasted to become one of the countries most affected by climate change in the future. However, awareness of the impact of climate change on the agricultural economy is currently still very limited. This study was conducted to examine the impact of extreme weather events and climate change on value-added of agriculture and fishery enterprises in the Central and Central Highlands regions with an available panel data of 19 years from 2000 to 2018. The study applied the Ricardian model following the Hsiao two-stage estimation method. The novel point from this study is to integrate both components of extreme weather events and climate factors into the model to examine the impacts at the same time. In addition, the study also examined the impact of extreme weather events and climate change on the efficiency of enterprises by regions and economic sectors. The assessments of the interaction between precipitation factors and temperature in climate change as well as the interaction between the factors of extreme weather events and climate change by regions are also included in the model to more accurately reflect the impacts of relevant factors. The findings from this study imply that the impact of extreme weather events and climate change on value-added of agriculture and fishery enterprises in the Central and Central Highlands regions is large. Specifically, the impact by 2035, the value-added of the enterprise in the agriculture and fishery sectors will decrease about billion VND 3597.72 and VND 5280.37, respectively. It is estimated that by 2099, the value-added will decrease about billion VND 10,757.19 and 18,891.2, respectively. The estimated results from the model by regions shows that the Central Highlands is the region most affected by the impact of the temperature factor; however, it is also the region that benefits the most from the precipitation factor in comparison to the other regions. The South Central region is least affected by the temperature factor; however, it also benefits the least from the precipitation factor. In terms of economic sector, agriculture is the main sector in the Central region; therefore, the impact of extreme weather events and climate change on the agricultural sector is predicted to be the largest. The impacts of climate change can be mitigated if relevant stakeholders understand the trend and capture future technical changes to crops or farming techniques, to adapt in various conditions of extreme weather events and climate change such as: changing crop seasons, aquatic products, shifting crop structures, selecting highly resilient plant varieties, applying advanced technology in agricultural production, and aquaculture activities. The purpose of such solutions is to both adapt to the change in climate and to mitigate the negative impacts from climate change.

The Ricardian model is applied to quantify the impacts of future extreme weather events and climate change on agriculture and fishery enterprises. Estimated results were based on the hypothesis that the enterprises' technical systems in the future are still similar to the present. Therefore, estimated impacts of extreme weather events and climate change do not capture future technical change in enterprises' production process. To support for the analysis and findings, qualitative research has been applied via expert method

and questionnaire survey. However, surveys are only implemented in two representative provinces (Nghe An Province and Binh Thuan Province) in Central Vietnam. Besides, the study focuses only on evaluating the impact of storms and droughts on enterprises' value-added, the impact of some other important extreme weather events such as floods, soil salinity as well as the influence of the implementation of response measures to climate change on the output of the enterprises have not been assessed. These imply for further studies in the future.

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