SHORT-TERM CLIMATE VARIABILITY AND PROVINCIAL ECONOMIC GROWTH IN CENTRAL VIETNAM: EVIDENCE FROM PANEL DATA

BIẾN ĐỘNG KHÍ HẬU NGẮN HẠN VÀ HOẠT ĐỘNG KINH TẾ CẤP TỈNH Ở MIỀN TRUNG VIỆT NAM: PHÂN TÍCH DỮ LIỆU BẢNG

Bui Quang Binh[1], Nguyen Danh Khoi[1]*, Phan Ngoc Minh[2]

[1]*The University of Danang - University of Economics, Vietnam*
[2]*Central Power Corporation, Vietnam*

*Corresponding author: khoind@due.edu.vn

(Received: February 09, 2026; Revised: March 30, 2026; Accepted: April 24, 2026)

DOI: 10.31130/ud-jst.2026.24(4).090

Abstract - This study examines the impact of short-term climate variability on provincial per capita income in Central Vietnam during 2009–2024 using panel data from 11 provinces. A Climate Variability Index (CVI) is constructed to measure annual weather shocks. A fixed-effects model with Driscoll–Kraay standard errors is employed to control for unobserved provincial characteristics and address technical issues commonly associated with panel data. The results indicate that short-term climate variability has a statistically significant negative effect on local income, while urbanization and health infrastructure contribute positively to income improvement. Income inequality tends to exert an adverse effect under several model specifications. This study provides additional local-level empirical evidence on the economic effects of short-term climate shocks in the context of a developing economy.

Key words - Climate variability; GRDP per capita; Panel data; Fixed effects model; Central Vietnam.

Tóm tắt - Nghiên cứu này phân tích tác động của biến động khí hậu ngắn hạn đến thu nhập bình quân đầu người cấp tỉnh tại miền Trung Việt Nam giai đoạn 2009–2024 dựa trên dữ liệu bảng của 11 tỉnh. Chỉ số biến động khí hậu (CVI) được xây dựng nhằm đo lường các cú sốc thời tiết theo năm. Mô hình hiệu ứng cố định kết hợp sai số chuẩn Driscoll–Kraay được sử dụng để kiểm soát đặc điểm không quan sát được giữa các tỉnh và xử lý các vấn đề kỹ thuật trong dữ liệu bảng. Kết quả cho thấy biến động khí hậu ngắn hạn có tác động tiêu cực và có ý nghĩa thống kê đến thu nhập địa phương; trong khi đô thị hóa và cơ sở hạ tầng y tế góp phần cải thiện mức thu nhập. Bất bình đẳng thu nhập có xu hướng ảnh hưởng bất lợi trong một số đặc tả mô hình. Nghiên cứu cung cấp thêm bằng chứng thực nghiệm ở cấp địa phương về tác động kinh tế của các cú sốc khí hậu ngắn hạn trong bối cảnh một nền kinh tế đang phát triển.

Từ khóa - Biến động khí hậu; Thu nhập bình quân đầu người; Dữ liệu bảng; Mô hình tác động cố định; Miền Trung Việt Nam.

1. Introduction

Climate variability has increasingly become a significant source of risk to economic activity, particularly in developing economies that remain highly dependent on natural conditions. Beyond the extensive literature on long-term climate change, recent empirical evidence suggests that annual weather shocks—such as unusual fluctuations in temperature, rainfall, and sunshine duration—can disrupt production, consumption, and investment, thereby influencing short-run economic performance [1], [2].

However, the effects of climate variability are not uniform across regions, highlighting the need for spatially appropriate analysis. Recent regional studies in Central Vietnam have also documented significant temporal and spatial variation in hydro-meteorological conditions, reinforcing the importance of localized climate assessment [3]. Provincial-level panel data provide a more precise framework for identifying localized short-run climate effects, since weather shocks often influence local economies before broader spillover effects emerge.

Central Vietnam provides a particularly relevant empirical context because the region is frequently exposed to extreme weather events and annual climate fluctuations while also exhibiting substantial heterogeneity in natural conditions and development levels across provinces. These characteristics make it well suited for examining the relationship between short-term climate variability and provincial economic growth.

Accordingly, this study investigates the effects of short-term climate variability on provincial GRDP per capita in Central Vietnam during 2009–2024 using panel data, with the aim of clarifying how annual climate shocks shape local economic outcomes in the short run.

2. Theoretical background

2.1. Theoretical foundations

In economic analysis, climate and weather are typically treated as exogenous environmental factors that influence economic activity through multiple transmission channels. Unlike long-term climate change, short-term climate variability is primarily reflected in abnormal annual fluctuations in key climatic conditions. These fluctuations may generate immediate shocks to the economy. This effect is particularly evident in the short run, when economic agents have not yet had sufficient time to adjust their behavior and production structures.

Long-term climate change often affects economic growth through mechanisms of structural adjustment and capital accumulation. In contrast, annual weather shocks mainly creates temporary shocks to productivity, production, and income within individual short periods.

From a theoretical perspective, short-term climate shocks influence economic growth through several primary channels [1], [4], [5]. Adverse weather conditions may reduce labor productivity, particularly in climate-sensitive sectors such as agriculture, construction, and tourism. In addition, climate variability may disrupt production activities and supply chains, thereby affecting output and costs. Moreover, these shocks also affect income, consumption, and short-term investment decisions in the economy.

Modern growth theory suggests that short-term shocks, although not necessarily altering long-run growth trajectories, may still generate substantial short-run fluctuations, particularly in developing economies with limited adaptive capacity. Therefore, the analysis of annual climate variability should be approached from a short-run perspective, focusing on the direct relationship between weather shocks and local economic outcomes, rather than extrapolating to long-term adjustment mechanisms.

2.2. Overview of related empirical studies

Empirical research on the relationship between climate and economic growth has expanded substantially over recent decades, spanning multiple analytical levels, time horizons, and estimation strategies. These studies differ in terms of level of analysis, time frame, and estimation methods. A large body of national-level panel studies finds that climatic variables—particularly temperature and rainfall—significantly affect economic growth, with stronger effects often observed in low- and middle-income economies [1], [2]. These findings suggest that climate is not only an environmental factor but also an important economic factor affecting production efficiency and welfare.

In addition to long-term analyses, an increasingly important strand of research focuses on the short-term effects of cyclical annual climate changes. Evidence from [4] and [7] indicates that short-term fluctuations in temperature and rainfall may cause substantial disruptions to labor productivity and employment and directly affect people's quality of life, even if they do not necessarily alter long-term growth trends. Some other studies also indicate that the effects of weather shocks are nonlinear and depend on differences in the adaptive capacity of the economy, such as [8] and [9].

Because local economies tend to have lower levels of diversification and more limited adjustment capacity than national economies, climate shocks often exhibit clearer short-term effects; this has been documented in studies using panel data at the provincial or regional level. Studies by [10] and [11], for example, report the negative effects of extreme temperatures on output and productivity in U.S. states. Similarly, [12] and [5] show that climate variability may increase the instability of economic activities at the regional level, particularly in vulnerable localities.

Many studies indicate that the effects of climate variability in less developed countries are often stronger and less stable than in developed countries. Findings from studies in Asia, Africa, and Latin America show that short-term weather shocks may significantly affect agricultural production. Income and local economic activity are also clearly affected [13], [14], and [15]. However, the magnitude and direction of these effects are not consistent across studies. This divergence reflects differences in socioeconomic conditions as well as institutional contexts.

In Vietnam, existing studies have primarily focused on natural disasters, long-term climate trends, or broader structural drivers of regional growth. Recent provincial panel evidence in the Central and South Central regions has also emphasized the importance of localized socioeconomic conditions such as industrialization and urbanization in shaping regional economic performance [16]. However, provincial-level analyses specifically examining annual short-term climate variability and local income remain limited, particularly in Central Vietnam.

2.3. Research gap and hypothesis development

Despite the expanding literature on climate–growth interactions, existing research has predominantly focused on long-term climate change or national-level evidence, leaving annual short-term climate variability at the local level comparatively underexplored.

In addition, empirical evidence on the effects of short-term climate shocks remains relatively limited in developing countries. This is particularly true for studies using provincial-level panel data with an appropriate analytical framework. Therefore, the magnitude and direction of the effects of climate variability on short-term local economic outcomes have not yet been clearly identified.

In Vietnam, existing quantitative studies primarily examine natural disasters or long-term climate trends, while provincial-level analyses of annual short-term climate variability and per capita income remain limited, particularly in Central Vietnam. Based on this gap, the present study focuses on analyzing the relationship between annual weather shocks and provincial economic growth in Central Vietnam during the period 2009–2024, using panel data and a fixed-effects model.

From a theoretical perspective, abnormal annual fluctuations in climatic factors may be regarded as exogenous shocks to the short-term economic cycle. These fluctuations may affect income levels through various channels, including declines in labor productivity, disruptions in production activities and supply chains, as well as fluctuations in the income and consumption of economic agents. Empirical evidence also shows that short-term climate shocks often have negative effects on economic activity, especially in areas that are highly dependent on climate-sensitive sectors such as agriculture and tourism ([1], [2], and [4]).

In the context of the provinces of Central Vietnam, which are frequently subject to strong annual weather fluctuations and have economic structures that are relatively sensitive to climate conditions, climate variability is expected to generate short-term disruptions to local economic activity. On the basis of these arguments, the research hypothesis is formulated as follows:

H1: Short-term climate variability negatively affects provincial GRDP per capita.

This hypothesis implies that abnormal annual fluctuations in climate conditions, as identified through the Climate Variability Index (CVI), may reduce local economic activity in the short run.

3. Research methodology and data

3.1. Analytical framework

Building on the identified research gap, this study develops an analytical framework to examine the direct relationship between annual climate variability and provincial economic outcomes. Empirical framework builds on studies in climate economics, in which annual climate fluctuations are viewed as exogenous shocks, distinct from long-term climate change trends. These shocks may directly affect economic activity in the short run [1] and [4].

According to the analytical framework, short-term climate variability is measured through abnormal fluctuations in basic climatic factors, including temperature, rainfall, and sunshine duration. These shocks may affect local economic activity through multiple channels in the short run. These channels include reductions in labor productivity, disruptions to production and supply chains, as well as fluctuations in consumption and investment. The effects are often more pronounced in economies or regions with limited adaptive capacity [5], [6], and [7].

Provincial GRDP per capita is shaped not only by climate shocks but also by structural socioeconomic conditions; accordingly, the model incorporates control variables to isolate the net effect of annual climate variability. Therefore, the analytical framework employs a set of control variables to reflect the level of urbanization, health and social conditions, income distribution, and related macroeconomic factors. Including these variables in the model identify net effects the effect of annual weather shocks on economic outcomes, consistent with the common approach in empirical studies on climate economics [2], [17].

The analytical framework is implemented using provincial-level panel data, which allows the exploitation of temporal variation within each locality and the control of time-invariant unobserved characteristics across provinces through a fixed-effects model.

3.2. Model Specification

Based on the established research gap, this study employs a panel data model to analyze the impact of annual climate variability on economic activity at the provincial level. empirical framework allows the exploitation of time variation within each locality while controlling for unobserved province-specific characteristics. As a result, the model captures the relationship between annual climate shocks and short-term local economic fluctuations. The empirical specification is expressed as follows:

$$Income_{it} = \beta_0 + \beta_1 \mathrm{CVI}_{it} + \beta_2 \mathrm{Health}_{it} + \beta_3 Urban_{it} + \beta_4 \mathrm{CPI}_{it} + \beta_5 \mathrm{Tourism}_{it} + \beta_6 \mathrm{Gini}_{it} + \mu_i + \varepsilon_{it} \quad (1)$$

Where $Income_{it}$ denotes the natural logarithm of provincial GRDP per capita (2010 constant prices), CVI_{it} represents the Climate Variability Index, μ_i captures time-invariant province-specific effects, and ε_{it} is the idiosyncratic error term.

The control variables include Urban, measured by the logarithm of the urban population to capture the level of urbanization; Health, measured by the logarithm of hospital beds per capita as a proxy for health and social conditions; Tourism, measured by the logarithm of tourism revenue to reflect tourism activity; CPI, representing provincial macroeconomic stability through the consumer price index; and Gini, capturing the degree of income inequality across localities.

In addition, the unobserved error component specific to each province is denoted by μ_i, reflecting province-specific characteristics that are constant over time. Including the control variables in the model helps reduce bias arising from socioeconomic factors while isolating the effect of short-term climate variability on economic outcomes.

3.3. Estimation Strategy

The study applies panel data analysis to estimate the effects of annual climate variability on provincial per capita income. Before estimation, a sequence of specification tests is conducted to determine the appropriate panel-data estimator and ensure empirical consistency.

Specifically, the Breusch–Pagan LM test assesses the presence of panel effects, the F-test compares pooled OLS with fixed effects, and the Hausman test determines the choice between fixed and random effects. Finally, the Hausman test is applied to choose between the fixed-effects model and the random-effects model. This selection is based on the assumption regarding the correlation between the individual effects and the explanatory variables.

Table 1. *Panel data model selection tests*

Test	Purpose	Test statistic	p-value	Conclusion
Breusch–Pagan LM	Panel vs. pooled	χ^2 = 391.98	0.000	Panel effects exist
F-test (FE)	FE vs. pooled	F = 43.57	0.000	FE model selected
Hausman	FE vs. RE	χ^2 = 21.40	0.0016	FE model selected

(Source: Author's calculations)

The test results reported in Table 1 indicate that the province fixed-effects model is the appropriate specification for analyzing the dataset [18]. Accordingly, the subsequent estimations and analyses are conducted based on this model.

In addition to model selection, the study also examines the error properties in the panel data. The Wooldridge [19] test for serial correlation indicates the presence of firstorder serial correlation in the error term (F = 233.08; $p < 0.01$). At the same time, the modified Wald test for heteroskedasticity also indicates the presence of heteroskedasticity across observational units ($\chi^2 = 126.30$; $p < 0.01$). Given the presence of serial correlation and heteroskedasticity, the study employs Driscoll–Kraay standard errors within the fixed-effects framework to obtain robust inference under serial correlation, heteroskedasticity, and cross-sectional dependence [20].

In the baseline model, the study uses year fixed effects to control for common macro-level characteristics over time across localities. Empirical framework is also treated as a robustness check, helping to remove the influence of annual macroeconomic shocks. At the same time, combining year fixed effects with province fixed effects helps reduce bias arising from unobserved factors, thereby providing a clearer picture of the effect of short-term climate variability.

3.4. Data and Variable Construction

The study uses provincial-level panel data for Central Vietnam, covering 11 provinces over the period 2009–2024. The provinces in the sample include Thanh Hoa, Nghe An, Ha Tinh, Quang Binh, Quang Tri, Thua Thien Hue, Da Nang, Quang Nam, Quang Ngai, Binh Dinh, and Phu Yen. The study period is selected to reflect the context of socioeconomic and climatic fluctuations in this region in recent years.

Socioeconomic data are compiled for the period 2009–2024 from the Statistical Yearbooks of the provinces in Central Vietnam [20]. Per capita income is measured as the natural logarithm of GRDP per capita at 2010 constant prices.

Climate data are obtained from official sources, primarily the Vietnam Meteorological and Hydrological Administration and national climate databases. The climate variables include annual average temperature, annual rainfall, and annual sunshine duration. On this basis, the CVI is constructed to reflect the degree of abnormal annual fluctuations in climatic factors relative to their long-term average values.

For each climatic factor k, including temperature, rainfall, and sunshine duration, the data are standardized to eliminate inherent differences in climatic conditions across localities:

$$Z_{kit} = \frac{X_{kit} - \bar{X}_{ki}}{\sigma_{ki}}$$

where X_{kit} is the value of climatic factor k in province i and year t, while $\bar{X}_{ki}$ and σ_{ki} denote, respectively, the mean and standard deviation of factor k in province i over the entire study period.

The CVI is constructed by aggregating the fluctuations of the climatic factors after standardization for each year:

$$CVI_{it} = \sqrt{\frac{1}{K}\sum_{k=1}^{K} Z_{kit}^2}$$

where K is the number of climatic factors included in the index calculation. This construction captures annual climate instability at the provincial level while minimizing distortions arising from differences in measurement units across climatic indicators.

Constructing the CVI in this way is consistent with the objective of analyzing short-term economic effects, when annual climate fluctuations may create direct shocks to local economic activity. Therefore, in this study, the CVI is understood as a measure of weather shocks rather than a reflection of long-term climate change trends.

The control variables include the level of urbanization, represented by the logarithm of the urban population; health and social conditions, measured by the logarithm of the number of hospital beds per capita; and the consumer price index (CPI), reflecting inflation and the level of macroeconomic stability at the provincial level. CPI data are compiled from provincial Statistical Yearbooks and used in the form of the annual average index.

In addition, to consider the degree of income inequality, the study uses the provincial-level Gini index. These data are compiled from household living standards surveys published by the General Statistics Office, combined with related statistical sources. For years with missing data, the Gini index is linearly interpolated based on adjacent years, similar to the approach adopted in some previous empirical studies. Including this variable in the model helps capture differences in income distribution across localities over time.

Table 2. *Description of variables used in the model*

Symbol	Definition	Role	Data source
Income	Natural logarithm of GRDP per capita (2010 constant prices)	Dependent variable	[21]
CVI	Climate Variability Index based on standardized annual deviations in temperature, rainfall, and sunshine duration	Main explanatory variable	Author's calculation
Health	Natural logarithm of the number of hospital beds per 10,000 people	Control	[21]
Urban	Natural logarithm of urban population	Control	[21]
CPI	Average annual CPI	Control	[21]
Tourism	Natural logarithm of tourism revenue	Control	[21]
Gini	Gini coefficient measuring income inequality	Control	[21], [22] + interpolation

(Source: Author's compilation and calculations)

4. Results and discussion

4.1. Descriptive statistics

Table 3 presents the descriptive statistics of the variables used in the research model for 11 provinces in Central Vietnam over the period 2009–2024. The variables exhibit sufficient variation across provinces and over time, reflecting substantial heterogeneity in socioeconomic and climatic conditions across the study region.

Table 3. *Descriptive statistics*

Variable	Mean	Standard deviation	Minimum	Maximum
Income	3.357	0.318	2.674	4.028
CVI	0.799	0.351	0.192	1.951
Health	3.550	0.331	2.888	4.391
Urban	13.317	0.508	12.159	14.346
CPI	91.447	3.036	84.070	97.890
Tourism	5.608	1.132	1.030	8.172
Gini	0.379	0.029	0.258	0.419

(Source: Processed from statistical data of Central provinces and the Ministry of Information and Communications)

The dependent variable, measured as the logarithm of GRDP per capita, has a mean value of 3.357 with a standard deviation of 0.318. This result indicates the existence of substantial differences in the level of economic development across provinces. The range from the minimum to the maximum value also reflects clear income disparities within the research sample.

The CVI has a mean value of 0.799 and a standard deviation of 0.351, indicating considerable differences in the degree of climate fluctuation across provinces over time. The range of variation in the CVI suggests that localities in the region are not only affected by their specific climatic conditions, but also face weather shocks whose intensity changes over time.

Regarding the control variables, Health (the logarithm of the number of hospital beds per 10,000 people) and Urban (the logarithm of the urban population) both show relatively stable variation, reflecting differences in health conditions and levels of urbanization across provinces. In addition, the CPI has a mean value of 91.447 and a standard deviation of 3.036, with no significant outliers. The Gini index has a mean value of 0.379, with relatively low variation, suggesting that differences in income distribution across localities are not excessively large.

Overall, the descriptive statistics indicate meaningful cross-provincial and temporal variation in both climatic and socioeconomic variables, supporting the suitability of the dataset for panel-data estimation. In particular, the variation in CVI confirms substantial differences in annual climate instability across provinces and over time.

4.2. Estimation results from the fixed-effects model with DKSE standard errors

Table 4 reports the baseline FE–DKSE estimates, which are statistically robust overall and broadly consistent with theoretical expectations.

The coefficient on CVI is negative and statistically significant at the 1% level (β = -0.0844), indicating that greater annual climate instability is associated with lower provincial GRDP per capita in the short run. This finding suggests that annual weather shocks may disrupt local economic activity, particularly in Central Vietnam, where dependence on climate-sensitive sectors remains relatively high.

Table 4. *Regression results of the FE-DKSE model*

Variable	Coefficient	Standard error	t	P>|t|
CVI	-0.0844***	0.0232	-3.64	0.002
Health	0.4875***	0.0797	6.12	0.000
Urban	0.6019***	0.0746	8.07	0.000
CPI	0.000080***	0.000021	3.86	0.002
Tourism	0.0329***	0.0098	3.37	0.004
Gini	-1.6443*	0.8802	-1.87	0.081
_cons	-5.8983***	1.0778	-5.47	0.000

*Notes: ***, **, * denote significance levels of 1%, 5%, and 10%, respectively. N = 176; Number of provinces = 11; Within* $R^2 = 0.836$

(Source: Author's calculations)

Among the control variables, urbanization, health infrastructure, tourism activity, and CPI all exhibit positive and statistically significant associations with provincial income, suggesting that structural socioeconomic capacity may partially offset climate-related vulnerability. Urbanization appears particularly important, consistent with its role in enhancing productivity, labor mobility, and broader economic opportunities. The positive coefficient on tourism further highlights the contribution of service-sector development to local economic performance. Meanwhile, the positive CPI coefficient may reflect short-run macroeconomic expansion rather than a direct welfare-enhancing effect of inflation itself. Although the Gini coefficient is only weakly significant at the 10% level, its negative sign suggests that income inequality may constrain provincial economic performance under certain conditions.

Overall, the estimation results from the FE–DKSE model provide empirical evidence that short-term climate variability has an adverse effect on provincial per capita income, even after controlling for important socioeconomic factors.

4.3. Robustness checks

To evaluate the robustness of the baseline findings, the study estimates several alternative model specifications by incorporating additional temporal controls, lag structures, and endogeneity-mitigating adjustments. Specifically, three robustness strategies are employed: *(i) adding year fixed effects to control for common macroeconomic shocks over time, (ii) introducing the lagged climate variable, and (iii) incorporating lagged control variables to reduce potential endogeneity concerns*. The corresponding results are reported in Table 5.

When year fixed effects are introduced, the coefficient on CVI remains negative and statistically significant at the 10% level, although its magnitude declines relative to the baseline estimate (from -0.0844 to -0.0313). This pattern suggests that part of the variation in provincial GRDP per capita is associated with broader temporal dynamics; however, the adverse short-run effect of climate variability remains robust after controlling for common macroeconomic shocks.

Table 5. *Robustness checks of estimation results*

Model specification	*Climate variable*	*Coefficient*	*Significance*
FE-DKSE + Year FE	CVI	-0.0313	*
FE-DKSE (lag)	L.CVI	-0.0384	**
FE-DKSE + lag controls	CVI	-0.0342	**

(Source: Author's calculations)

When the lagged value of CVI is included, the coefficient remains negative and statistically significant at the 5% level (-0.0384), suggesting that the economic effects of climate shocks may persist into the subsequent period. Similarly, when lagged control variables are incorporated to mitigate potential endogeneity, the coefficient on CVI remains negative and statistically significant at the 5% level (-0.0342). These results reinforce that the inverse relationship between climate variability and provincial income is not driven solely by contemporaneous specification choices, but remains stable across alternative model structures.

Overall, all robustness checks consistently confirm the negative association between climate variability and provincial GRDP per capita across alternative specifications. Although the magnitude of the coefficient declines when additional temporal controls and lag structures are introduced, the sign and statistical significance remain broadly stable. This consistency strengthens confidence in the core empirical finding that short-term climate variability adversely affects local economic performance, while also suggesting appropriate caution given the study's sample size limitations.

4.4. Discussion

The baseline estimates and robustness checks consistently indicate that short-term climate variability, as measured by the CVI, exerts a negative effect on provincial GRDP per capita in Central Vietnam. This finding supports the research hypothesis that annual weather shocks may disrupt local economic activity even after controlling for key socioeconomic factors.

This result is consistent with prior empirical studies showing that short-term climate shocks often reduce productivity and economic growth, particularly in developing economies that remain highly dependent on natural conditions. In the context of Central Vietnam, where agriculture, tourism, and coastal services are especially climate-sensitive, annual weather instability may disrupt production chains, reduce labor productivity, and weaken household income and consumption, thereby constraining short-term local economic outcomes.

In addition, the control variables suggest that structural socioeconomic factors—including urbanization, health infrastructure, and tourism development—are positively associated with provincial income, indicating that stronger local socioeconomic capacity may partially mitigate climate-related vulnerability. However, because these variables are incorporated primarily as controls, the study does not directly examine their mediating or interactive roles in shaping climate-related economic effects. By contrast, the negative coefficient on the Gini index suggests that income inequality may constrain local economic performance, although this relationship remains relatively weak in the baseline specification.

Compared with studies emphasizing long-term climate change or national-level evidence, the present findings highlight the importance of examining annual short-term climate variability at the local level. This empirical framework helps clarify the direct transmission channels through which weather shocks affect provincial economic performance in the short run, while also extending the climate economics literature in the context of transitional and developing economies. These findings suggest that focusing exclusively on long-term trends may underestimate the immediate economic consequences of localized climate instability.

5. Conclusion and policy implications

5.1. Conclusion

This study examines the effects of annual climate variability on provincial GRDP per capita in Central Vietnam during 2009–2024 using panel data and the FE–DKSE framework. The empirical results indicate that annual climate shocks exert a negative effect on local economic performance, and this relationship remains robust after controlling for key socioeconomic factors.

A key contribution of this study lies in its short-run, local-level analytical perspective on climate variability, rather than focusing primarily on long-term climate trends or national-level evidence. This approach helps clarify the direct transmission channels through which annual weather shocks influence provincial economic outcomes in a developing regional context.

The findings also provide additional empirical evidence on how structural socioeconomic conditions shape local economic resilience under climate-related pressures, thereby extending the climate economics literature at the subnational level within developing economies.

Nevertheless, several limitations should be acknowledged. The CVI is constructed from basic climatic indicators and therefore may not fully capture the intensity of extreme weather events. In addition, data limitations for certain control variables require interpolation in some cases. Future research may strengthen this framework by incorporating broader climate-risk indicators, extreme-event measures, and higher-frequency local data.

5.2. Policy implications

Based on the empirical findings, several policy implications emerge for mitigating the adverse economic effects of climate variability in Central Vietnam.

First, strengthening local adaptive capacity should be a central policy priority. Regional development strategies should place greater emphasis on climate-sensitive sectors such as agriculture, tourism, and coastal services, while simultaneously expanding investment in climate forecasting systems, disaster preparedness, and climate-risk management infrastructure.

Second, the positive role of urbanization suggests that economic diversification beyond climate-vulnerable sectors is essential. Urban development, service-sector expansion, and regional infrastructure planning should be integrated with climate adaptation objectives to reduce structural dependence on weather-sensitive activities.

Third, the adverse association between income inequality and economic performance highlights the importance of inclusive resilience policies. Strengthening social protection systems, reducing inequality, and improving adaptive capacity among vulnerable populations may enhance both social stability and regional economic resilience under climate-related stress.

Overall, the findings emphasize that sustainable regional growth in the context of increasing climate variability requires the integration of socioeconomic development strategies with localized climate adaptation planning.

REFERENCES

[1] M. Dell, B. F. Jones, and B. A. Olken, "Temperature shocks and economic growth: Evidence from the last half century", *American Economic Journal: Macroeconomics*, vol. 4, no. 3, pp. 66–95, 2012. https://doi.org/10.1257/mac.4.3.66

[2] M. Burke, S. M. Hsiang, and E. Miguel, "Global non-linear effect of temperature on economic production", *Nature*, vol. 527, pp. 235–239, 2015. https://doi.org/10.1038/nature15725

[3] S. M. Hsiang, "Climate econometrics," *Annual Review of Resource Economics*, vol. 8, pp. 43–75, 2016. https://doi.org/10.1146/annurev-resource-100815-095343

[4] D. T. N. Canh, L. Dan, and V. N. Duong, "Nonparametric estimation approach for evaluating the trend of hydro-meteorological factors in Quang Nam - Da Nang", *The University of Danang - Journal of Science and Technology*, vol 19, no. 1, pp. 8–13, 2021

[5] M. E. Kahn, K. Mohaddes, R. N. Ng, M. H. Pesaran, M. Raissi, and J. C. Yang, "Long-term macroeconomic effects of climate change: A cross-country analysis", *Energy Economics*, vol. 104, Art. no. 105624, 2021. https://doi.org/10.1016/j.eneco.2021.105624

[6] M. Burke and V. Tanutama, "Climatic constraints on aggregate economic output", *Journal of Economic Growth*, vol. 24, no. 1, pp. 1–34, 2019.

[7] T. Deryugina and S. M. Hsiang, "The marginal product of climate", NBER Working Paper No. 24072, 2017. https://doi.org/10.3386/w24072

[8] G. Heal and J. Park, "Reflections—Temperature stress and the direct impact of climate change", *Review of Environmental Economics and Policy*, vol. 10, no. 2, pp. 347–362, 2016. https://doi.org/10.1093/reep/rew007

[9] T. A. Carleton and S. M. Hsiang, "Social and economic impacts of climate", *Science*, vol. 353, no. 6304, Art. no. aad9837, 2016. https://doi.org/10.1126/science.aad9837

[10] O. Deschênes and M. Greenstone, "Climate change, mortality, and adaptation: Evidence from annual fluctuations in weather", *American Economic Journal: Applied Economics*, vol. 3, no. 4, pp. 152–185, 2011. https://doi.org/10.1257/app.3.4.152

[11] R. Colacito, B. Hoffmann, and T. Phan, "Temperature and growth: A panel analysis of the United States", *Journal of Money, Credit and Banking*, vol. 51, no. 2–3, pp. 313–368, 2019. https://doi.org/10.1111/jmcb.12574

[12] M. Letta and R. S. J. Tol, "Weather, climate and economic growth", *Environmental and Resource Economics*, vol. 72, no. 2, pp. 343–364, 2019.

[13] C. Brown, R. Meeks, Y. Ghile, and K. Hunu, "An empirical analysis of the effects of climate variables on national level economic activity", World Bank Policy Research Working Paper No. 5357, 2010.

[14] M. Auffhammer, S. M. Hsiang, W. Schlenker, and A. Sobel, "Using weather data and climate model output in economic analyses of climate change", *Review of Environmental Economics and Policy*, vol. 7, no. 2, pp. 181–198, 2013. https://doi.org/10.1093/reep/ret016

[15] S. Acevedo, M. Mrkaic, N. Novta, E. Pugacheva, and P. Topalova, "The effects of weather shocks on economic activity: How can low-income countries cope?", *World Bank Economic Review*, vol. 32, no. 3, pp. 1–23, 2018.

[16] N. D. Khoi, "The impact of industrialization and urbanization on economic growth in the Central and South Central regions", *The University of Danang - Journal of Science and Technology*, vol 23, no. 8A, 2025, https://doi.org/10.31130/ud-jst.2025.23(8A).241

[17] M. Dell, B. F. Jones, and B. A. Olken, "What Do We Learn from the Weather? The New Climate–Economy Literature", *Journal of Economic Literature*, vol. 52, no. 3, pp. 740–798, 2014. https://doi.org/10.1257/jel.52.3.740

[18] W. H. Greene, *Econometric Analysis*, 8th ed. New York, NY, USA: Pearson Education, 2018.

[19] J. M. Wooldridge, *Econometric Analysis of Cross Section and Panel Data*, 2nd ed. Cambridge, MA, USA: MIT Press, 2010.

[20] J. C. Driscoll and A. C. Kraay, "Consistent covariance matrix estimation with spatially dependent panel data", *Review of Economics and Statistics*, vol. 80, no. 4, pp. 549–560, 1998. https://doi.org/10.1162/003465398557825

[21] General Statistics Office of Vietnam (GSO), *Statistical Yearbook of the Central Provinces of Vietnam (2009–2024)*. Hanoi, Vietnam: Statistical Publishing House.

[22] General Statistics Office of Vietnam (GSO), *Statistical Yearbook of Vietnam (2009–2024)*. Hanoi, Vietnam: Statistical Publishing House.