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Sustainable Finance, Climate Vulnerability, and Gendered Productivity Losses: Evidence from Heat Stress Exposure and Institutional Adaptive Capacity in Emerging Economies

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Abstract

This study examines the role of sustainable finance in mitigating climate-induced gendered productivity losses in emerging economies. Using a balanced panel of 38 emerging countries over the period 2000–2024, the study analyzes how heat stress exposure affects female labour productivity and whether sustainable finance (green finance and ESG investment) and institutional adaptive capacity moderate these effects. The empirical strategy employs Panel ARDL (PMG), System GMM, and CCEMG estimators to address heterogeneity, endogeneity, and cross-sectional dependence. The results indicate that heat stress significantly reduces female labour productivity, particularly in climate-sensitive and informal sectors. Sustainable finance demonstrates a statistically significant positive effect on productivity, suggesting its role in enhancing climate resilience through efficient capital reallocation. Institutional adaptive capacity further strengthens this effect by improving policy implementation and environmental governance. Interaction results confirm that both ESG investment and institutional quality significantly mitigate the adverse productivity effects of climate stress. The findings highlight that climate vulnerability is not only an environmental issue but also a financial and institutional challenge with strong gendered implications. The study contributes to the literature on climate economics, sustainable finance, and gender inequality by providing integrated empirical evidence from emerging economies. Policy recommendations emphasize strengthening ESG frameworks, expanding green finance instruments, and improving institutional governance to reduce climate-induced gender disparities.

Keywords: Sustainable Finance; ESG Investment; Climate Vulnerability; Heat Stress; Gendered Productivity; Institutional Quality; Emerging Economies

1. Introduction

Climate change has become one of the most pressing global challenges of the twenty-first century, exerting profound effects on economic productivity, labour markets, public health, and sustainable development. Among the various climate-related hazards, rising temperatures and prolonged heatwaves have emerged as significant threats to labour productivity, particularly in emerging economies where large proportions of the workforce are employed in climate-sensitive sectors such as agriculture, construction, manufacturing, and informal services. Heat stress reduces workers' physical endurance, cognitive performance, and effective working hours,

resulting in lower productivity, declining household incomes, and slower economic growth. According to recent evidence, increasing heat exposure is projected to generate substantial global economic losses by reducing labour capacity, with developing countries facing the greatest burden because of higher baseline temperatures, limited technological adaptation, and weaker institutional systems. These impacts are expected to intensify under future climate scenarios, making heat stress a major concern for sustainable economic development.

Emerging economies are particularly vulnerable to climate change because their productive sectors remain highly dependent on natural resources, while financial constraints and institutional weaknesses limit their capacity to adapt effectively. Climate vulnerability extends beyond physical exposure to climatic hazards and reflects the interaction between environmental risks, socioeconomic sensitivity, and institutional adaptive capacity. Countries with weak governance, inadequate public infrastructure, limited access to climate finance, and insufficient disaster preparedness experience significantly greater economic disruptions following climate shocks. Consequently, enhancing adaptive capacity has become a central objective of international climate policy, particularly under the Sustainable Development Goals (SDGs) and the Paris Agreement. Recent assessments emphasize that institutional quality and governance effectiveness are essential determinants of successful climate adaptation and resilience in developing economies.

In response to escalating climate risks, sustainable finance has emerged as a critical mechanism for mobilizing financial resources toward environmentally sustainable and socially inclusive investments. Sustainable finance encompasses green bonds, environmental, social and governance (ESG) investments, climate adaptation funds, sustainable banking, carbon markets, and other financial instruments designed to promote low-carbon development and climate resilience. By directing capital toward renewable energy, resilient infrastructure, climate-smart agriculture, occupational safety, and technological innovation, sustainable finance can reduce climate vulnerability while enhancing long-term economic productivity. Recent empirical evidence indicates that countries with more developed sustainable finance systems tend to experience stronger environmental performance and greater resilience to climate-related shocks. Nevertheless, substantial financing gaps persist across many emerging economies because of limited financial market development, regulatory weaknesses, and governance challenges, constraining the effectiveness of climate adaptation initiatives.

An increasingly important dimension of climate vulnerability concerns its unequal effects on women and men. Gendered productivity losses arise because women frequently face structural inequalities in labour markets, lower access to financial resources, limited ownership of productive assets, restricted decision-making power, and disproportionate responsibilities for unpaid care work. These inequalities make female workers more susceptible to the adverse effects of heat stress, particularly in agriculture, textile manufacturing, informal employment, and other labour-intensive occupations. Heat exposure not only reduces women's productivity but also increases health risks, caregiving burdens, and income insecurity, thereby reinforcing existing socioeconomic disparities. Recent gender and climate studies conclude that women experience higher climate vulnerability due to unequal access to adaptation resources, financial services, education, healthcare, and institutional support. Consequently, integrating gender considerations into climate adaptation and sustainable finance policies has become increasingly important for achieving inclusive economic development.

The effectiveness of sustainable finance in reducing climate-induced productivity losses depends not only on the availability of financial resources but also on the strength of institutional adaptive capacity. Institutional adaptive capacity refers to the ability of governments, regulatory agencies,

and public institutions to design, implement, and coordinate effective climate adaptation policies while ensuring efficient allocation of financial resources. Strong institutions improve governance quality, policy implementation, financial transparency, public investment efficiency, disaster preparedness, and social protection systems, thereby enhancing the resilience of workers and communities to climate-related shocks. Conversely, institutional weaknesses often reduce the effectiveness of climate finance, resulting in inefficient resource allocation and limited adaptation outcomes. Emerging evidence demonstrates that governance quality significantly moderates the relationship between climate finance and sustainable development by improving policy effectiveness and strengthening resilience against environmental risks.

Although the literature on sustainable finance, climate vulnerability, labour productivity, and gender inequality has expanded considerably during the past decade, important knowledge gaps remain. Existing studies generally examine sustainable finance and climate adaptation separately, while relatively few investigate how sustainable finance can mitigate gendered productivity losses resulting from heat stress exposure. Likewise, empirical analyses rarely incorporate institutional adaptive capacity as a moderating factor linking climate finance and labour productivity. Furthermore, most previous studies rely on single-country analyses or conventional econometric techniques that do not adequately address cross-sectional dependence, heterogeneity, and endogeneity across countries. Consequently, there remains limited evidence regarding the integrated relationships among sustainable finance, climate vulnerability, heat stress exposure, institutional quality, and gendered labour productivity across emerging economies.

The present study addresses these research gaps by developing a comprehensive panel-data framework to examine the effects of sustainable finance, climate vulnerability, heat stress exposure, and institutional adaptive capacity on gendered productivity losses in emerging economies. Using a balanced panel of emerging countries over the period 2000–2024 and applying advanced second-generation panel econometric techniques—including Cross-Sectionally Augmented Autoregressive Distributed Lag (CS-ARDL), Common Correlated Effects Mean Group (CCEMG), Augmented Mean Group (AMG), Fully Modified Ordinary Least Squares (FMOLS), Dynamic Ordinary Least Squares (DOLS), and System Generalized Method of Moments (System GMM)—the study aims to provide robust empirical evidence on the long-run relationships among these variables. By integrating climate finance, institutional economics, and gender perspectives into a unified analytical framework, the study contributes to the growing literature on climate-resilient development and offers policy recommendations for designing gender-responsive adaptation strategies that strengthen labour productivity, reduce climate vulnerability, and promote sustainable economic growth in emerging economies.

1.1 Research Objectives

1. Examine the impact of sustainable finance on female labour productivity.
2. Investigate how heat stress exposure influences gendered productivity losses.
3. Assess the role of climate vulnerability in determining labour productivity.
4. Evaluate whether institutional adaptive capacity moderates the relationship between sustainable finance and productivity.
5. Develop policy recommendations for gender-inclusive climate adaptation.

1.2 Research Questions

- Does sustainable finance reduce gendered productivity losses?
- How does heat stress affect female labour productivity?
- Does institutional quality strengthen climate adaptation?
- Can sustainable finance offset productivity losses under severe climate vulnerability?

1.3 Hypotheses

H1: Sustainable finance positively affects female labour productivity.

H2: Heat stress exposure negatively affects female labour productivity.

H3: Climate vulnerability increases productivity losses.

H4: Institutional adaptive capacity positively moderates the effectiveness of sustainable finance.

H5: Sustainable finance and institutional quality jointly reduce gender disparities.

2. Literature Review

The literature indicates that sustainable finance mobilizes capital toward climate adaptation and resilience, but its effectiveness depends on governance quality and institutional capacity. Studies find that stronger institutions improve the productivity impacts of climate finance and enhance resilience in developing economies.

Research on gender and climate vulnerability highlights that women often face disproportionate climate risks because of structural inequalities in access to resources, decision-making, and adaptation opportunities. Empowerment and inclusive institutions are associated with stronger climate resilience.

2.1 Introduction

Climate change has become one of the greatest threats to sustainable economic development, particularly in emerging economies where institutional weaknesses, limited adaptive capacity, and financial constraints amplify climate risks. Rising temperatures and increasing frequency of heatwaves directly affect labour productivity by reducing workers' physical capacity, cognitive performance, and working hours.

Women experience disproportionately larger productivity losses because they are overrepresented in climate-sensitive sectors such as agriculture, informal employment, textile manufacturing, and unpaid household work. Consequently, sustainable finance has emerged as a critical policy instrument for mobilizing resources toward climate adaptation, resilience building, and gender-inclusive development. However, the effectiveness of sustainable finance largely depends on institutional adaptive capacity, governance quality, and the ability of governments to channel financial resources into productive climate-resilient investments. Recent reviews also highlight that sustainable finance remains unevenly distributed across emerging markets and that stronger governance and ESG frameworks are essential for improving adaptation outcomes.

2.2 Theoretical Foundations

The proposed research is grounded in five complementary theories that explain the relationships among climate finance, institutional quality, climate vulnerability, and labour productivity.

2.1 Sustainable Finance Theory

Sustainable Finance Theory argues that financial systems should allocate capital toward investments that simultaneously generate economic returns and environmental and social benefits. Sustainable finance encompasses green bonds, climate funds, ESG investments, carbon markets, sustainable banking, and climate adaptation financing. By directing financial resources toward renewable energy, resilient infrastructure, climate-smart agriculture, and occupational adaptation technologies, sustainable finance can reduce climate-related productivity losses while supporting inclusive economic growth. Recent reviews emphasize that government policy, investor preferences, ESG infrastructure, and regulatory quality are central determinants of sustainable finance flows, especially in emerging economies.

2.2.2 Climate Vulnerability Theory

Climate Vulnerability Theory explains that the economic impacts of climate change depend on three interconnected dimensions:

- Exposure to climate hazards
- Sensitivity of socioeconomic systems
- Adaptive capacity

Emerging economies typically experience higher vulnerability because economic activities remain highly dependent on climate-sensitive sectors while institutional capacities and financial resources for adaptation remain relatively weak. Women are generally more vulnerable because of unequal access to productive assets, education, finance, healthcare, and decision-making institutions. Recent syntheses show that governance quality and equitable access to adaptation resources are decisive in reducing vulnerability.

2.2.3 Human Capital Theory

Human Capital Theory views labour productivity as a function of workers' health, education, skills, and physical capacity. Heat stress directly reduces human capital by increasing fatigue, dehydration, illness, absenteeism, and cognitive impairment. Investments in occupational safety, healthcare, education, and adaptive technologies therefore improve productivity and strengthen resilience against climate shocks.

2.2.4 Institutional Economics Theory

Institutional Economics argues that strong institutions improve policy implementation, regulatory quality, transparency, and efficient allocation of public resources. High-quality institutions facilitate climate adaptation by ensuring that sustainable finance reaches vulnerable populations through effective governance, public investment, and climate-responsive policies. Conversely, institutional weaknesses limit the effectiveness of climate finance and reduce adaptive capacity.

2.2.5 Feminist Economics Theory

Feminist Economics emphasizes that labour markets are characterized by gender inequalities that influence productivity, income, employment opportunities, and access to productive resources. Climate change exacerbates these inequalities because women often work in occupations that are more vulnerable to extreme temperatures while simultaneously bearing greater unpaid care responsibilities. Gender-responsive climate policies and inclusive financial systems therefore become essential for reducing climate-induced productivity losses. Recent systematic reviews conclude that climate change intensifies existing gender disparities through constrained access to resources, health services, and decision-making opportunities.

2.3 Sustainable Finance and Climate Adaptation

The literature on sustainable finance has expanded rapidly following the Paris Agreement and the Sustainable Development Goals. Sustainable finance mobilizes capital toward projects that promote environmental sustainability while supporting long-term economic resilience.

Several studies argue that green bonds, ESG investment, climate funds, sustainable banking, and adaptation finance significantly increase investments in renewable energy, resilient infrastructure, and disaster preparedness. These investments reduce climate vulnerability and improve labour productivity by lowering exposure to environmental risks. Recent systematic reviews identify adaptation finance as a key mechanism for supporting vulnerable regions, although major financing gaps remain in many emerging economies.

Despite increasing investment, researchers note that climate finance remains concentrated in developed countries, while emerging economies continue to face shortages of adaptation finance because of institutional weaknesses, limited financial markets, and governance

constraints. Consequently, strengthening institutional quality has become increasingly important for improving the effectiveness of sustainable finance.

2.4 Climate Vulnerability and Heat Stress

Climate vulnerability reflects the susceptibility of individuals, firms, and economies to climate-related hazards. Heat stress has become one of the most important channels through which climate change affects labour productivity.

Heat exposure reduces workers' physical performance, increases fatigue, decreases concentration, and raises occupational health risks. Outdoor workers in agriculture, construction, manufacturing, mining, and transportation experience particularly severe productivity declines. A comprehensive systematic review estimates that heat-related labour productivity losses could reduce global GDP substantially under high-emissions scenarios, with the greatest impacts occurring in South and Southeast Asia, Sub-Saharan Africa, and Central America.

Emerging economies face particularly severe challenges because high temperatures coincide with limited workplace cooling infrastructure, inadequate occupational safety standards, and weaker institutional adaptation capacity.

2.5 Gendered Productivity Losses under Heat Stress

The gender dimensions of climate vulnerability have received growing attention in recent years. Women frequently experience greater productivity losses than men because of occupational segregation, unequal access to finance, lower ownership of productive assets, and greater household caregiving responsibilities.

Studies indicate that climate change amplifies pre-existing gender inequalities through adverse health outcomes, increased caregiving burdens, water insecurity, and reduced economic opportunities. Women in low- and middle-income countries are especially vulnerable because of limited access to healthcare, education, financial services, and decision-making institutions. These structural disadvantages reduce adaptive capacity and increase the economic consequences of heat stress.

Consequently, many scholars advocate integrating gender-responsive adaptation into climate finance and development policies to improve resilience and reduce productivity losses.

2.6 Institutional Adaptive Capacity

Institutional adaptive capacity refers to the ability of governments and public institutions to design, implement, and enforce effective climate adaptation policies. Strong institutions improve coordination among government agencies, increase transparency, strengthen financial accountability, and facilitate efficient allocation of climate finance.

Empirical evidence suggests that countries with better governance quality experience higher adaptation effectiveness because public investments are more efficiently directed toward resilient infrastructure, occupational safety, healthcare, and early warning systems. Governance-centered reviews also emphasize that fragmented institutions and weak policy implementation constrain climate finance delivery and reinforce socioeconomic inequalities.

Institutional quality therefore plays both a direct role in improving productivity and an indirect role by increasing the effectiveness of sustainable finance.

2.7 Empirical Literature

Recent empirical studies consistently report that sustainable finance contributes to environmental sustainability, renewable energy development, and climate resilience. However, the effectiveness of climate finance varies considerably across countries depending on institutional quality, governance effectiveness, and financial market development.

Research on heat stress demonstrates a robust negative relationship between rising temperatures and labour productivity. Heat exposure reduces effective working hours, lowers output per worker, and increases healthcare costs. These impacts are particularly severe in agriculture, manufacturing, and informal employment sectors that dominate many emerging economies.

Gender-focused studies reveal that women experience greater climate vulnerability because of structural inequalities in labour markets, financial access, and social protection systems. Strengthening women's access to finance, education, technology, and decision-making improves adaptive capacity and reduces productivity losses.

Finally, governance and institutional studies conclude that institutional quality enhances the effectiveness of climate finance by improving public investment efficiency, policy implementation, and climate adaptation planning. This suggests that institutional adaptive capacity is likely to moderate the relationship between sustainable finance and labour productivity.

2.8 Research Gap

Despite the rapid expansion of research on climate finance and labour productivity, several important gaps remain:

1. Most studies examine sustainable finance or heat stress independently rather than within an integrated framework.
2. Existing research rarely investigates gendered labour productivity losses using cross-country panel data.
3. Limited evidence exists regarding the moderating role of institutional adaptive capacity in strengthening the effectiveness of sustainable finance.
4. Few studies combine climate vulnerability, heat stress exposure, sustainable finance, institutional quality, and gender outcomes in a unified econometric model for emerging economies.
5. Previous analyses often rely on conventional panel estimators and overlook advanced techniques such as CS-ARDL, CCEMG, AMG, FMOLS, DOLS, and System GMM, which better account for cross-sectional dependence, heterogeneity, and endogeneity.

Accordingly, this study fills these gaps by developing an integrated panel econometric framework that examines how sustainable finance and institutional adaptive capacity mitigate climate vulnerability and gendered productivity losses arising from heat stress exposure across emerging economies.

3: Research Methodology

3.1 Introduction

This study presents the research methodology adopted to examine the relationship among sustainable finance, climate vulnerability, heat stress exposure, institutional adaptive capacity, and gendered productivity losses in emerging economies. The study employs a quantitative research design based on balanced panel data covering 35 emerging economies over the period 2000–2024. Given the presence of globalization, climate spillovers, and cross-country interdependence, advanced second-generation panel econometric techniques are employed to address cross-sectional dependence, slope heterogeneity, endogeneity, and long-run dynamics. The methodology follows recent empirical studies in climate economics, sustainable finance, environmental economics, and development economics that recommend Cross-Sectionally Augmented Autoregressive Distributed Lag (CS-ARDL), Common Correlated Effects Mean Group (CCEMG), Augmented Mean Group (AMG), Fully Modified Ordinary Least Squares (FMOLS), Dynamic Ordinary Least Squares (DOLS), and System Generalized Method of Moments (System

GMM) estimators for macro-panel analyses. These approaches provide robust and consistent estimates in the presence of heterogeneous panel structures. Recent methodological reviews support the use of second-generation panel estimators when analyzing climate-related macroeconomic relationships because they account for cross-sectional dependence and heterogeneous responses across countries.

3.2 Research Design

This study employs an explanatory panel data research design to examine the impact of sustainable finance on female labour productivity under different levels of climate vulnerability and heat stress, while assessing the moderating role of institutional adaptive capacity. The design is suitable for analyzing causal relationships among economic, environmental, institutional, and gender-related variables across countries over time. The empirical analysis follows a systematic approach that includes descriptive statistics, correlation analysis, cross-sectional dependence testing, panel unit root and cointegration tests, long-run and dynamic panel estimations, robustness checks, moderation analysis, and diagnostic testing.

3.3 Population and Sample

The target population of this study comprises emerging economies classified by the International Monetary Fund (IMF) and the World Bank. The sample consists of 35 emerging economies observed annually over the period 2000–2024, forming an unbalanced panel dataset in which missing observations are addressed using standard panel-data techniques. The sample includes countries such as Pakistan, India, Bangladesh, China, Indonesia, Malaysia, Thailand, Vietnam, the Philippines, Brazil, Mexico, Turkey, South Africa, Egypt, Nigeria, Argentina, Chile, Colombia, Peru, Poland, Hungary, Romania, Morocco, Kenya, Sri Lanka, and other emerging economies. These countries were selected because they exhibit substantial variation in climate vulnerability, institutional quality, sustainable finance development, and gender equality, providing a diverse and appropriate sample for comparative panel data analysis.

3.4 Data Sources

The study relies exclusively on secondary panel data obtained from internationally recognized databases.

Variable	Source
Female Labour Productivity	World Bank (WDI), International Labour Organization (ILO)
Sustainable Finance Index	Climate Bonds Initiative, OECD Green Finance Database, IMF Climate Finance Database
Heat Stress Exposure (WBGT/Temperature Anomaly)	ERA5 Reanalysis (Copernicus), Berkeley Earth, NASA GISS
Climate Vulnerability Index	ND-GAIN Country Index
Institutional Adaptive Capacity	World Governance Indicators (WGI)
Female Labour Force Participation	ILOSTAT
Female Education	UNESCO Institute for Statistics
GDP per Capita	World Development Indicators
Trade Openness	World Development Indicators
Renewable Energy Consumption	International Energy Agency (IEA), WDI

Variable	Source
Urbanization	World Development Indicators

These datasets are widely used in climate finance and development research and provide internationally comparable indicators. The ND-GAIN index is commonly employed to measure country-level climate vulnerability and readiness, while the World Governance Indicators are widely used to proxy institutional quality.

3.5 Variable Measurement

Dependent Variable

Variable	Proxy	Expected Sign
Female Labour Productivity (FLP)	GDP per employed female worker	—

Independent Variables

Variable	Proxy	Expected Sign
Sustainable Finance (SF)	Sustainable Finance Index	+
Heat Stress (HS)	Wet Bulb Globe Temperature (WBGT)	—
Climate Vulnerability (CV)	ND-GAIN Vulnerability Index	—
Institutional Adaptive Capacity (IAC)	Composite WGI Index	+

Control Variables

Variable	Proxy	Expected Sign
Female Education	Average Years of Schooling	+
GDP per capita	Constant US\$	+
Urbanization	Urban Population (%)	±
Trade Openness	Trade/GDP	+
Renewable Energy	Renewable Energy Consumption (%)	+

Moderating Variable

Institutional Adaptive Capacity (IAC)

Interaction Term:

$SF \times IAC$

Expected coefficient:

Positive (+)

3.6 Model Specification

The baseline empirical model is specified as:

$$FLP_{it} = \beta_0 + \beta_1 SF_{it} + \beta_2 HS_{it} + \beta_3 CV_{it} + \beta_4 IAC_{it} + \beta_5 (SF \times IAC)_{it} + \beta_6 X_{it} + \mu_i + \lambda_t + \varepsilon_{it}$$

- PFLP = Female Labour Productivity
- SF = Sustainable Finance
- HS = Heat Stress Exposure
- CV = Climate Vulnerability
- IAC = Institutional Adaptive Capacity
- X = Vector of control variables
- μ_i = Country-specific effects
- λ_t = Time effects
- ε_{it} = Error term

3.7 Econometric Methodology

The study begins with descriptive statistics to summarize the characteristics of the data using the mean, median, minimum, maximum, standard deviation, skewness, and kurtosis. Pearson correlation analysis and the Variance Inflation Factor (VIF) are then used to examine the relationships among variables and detect multicollinearity. Cross-sectional dependence is tested using the Pesaran CD and Breusch–Pagan LM tests, while the Pesaran and Yamagata Delta test is applied to examine slope heterogeneity across countries. The stationarity of the variables is assessed using the second-generation CIPS and CADF panel unit root tests, followed by the Westerlund and Pedroni cointegration tests to determine the existence of a long-run relationship. Long-run coefficients are estimated using CS-ARDL, CCEMG, AMG, FMOLS, and DOLS estimators, while System GMM is employed to address endogeneity and dynamic effects. Furthermore, moderation analysis is conducted by including the interaction term between sustainable finance and institutional adaptive capacity ($SF \times IAC$) to examine whether institutional quality strengthens the impact of sustainable finance on female labour productivity. Finally, robustness checks using alternative estimators and diagnostic tests, including heteroskedasticity, serial correlation, cross-sectional dependence, VIF, Hansen J-test, Arellano–Bond AR(1) and AR(2), and residual stability tests, are performed to ensure the reliability and validity of the empirical results.

4: Results and Discussion

4.1 Introduction

This paper presents the empirical findings regarding the effects of sustainable finance, climate vulnerability, heat stress exposure, and institutional adaptive capacity on female labour productivity across 35 emerging economies during the period 2000–2024. The analysis follows a structured econometric procedure beginning with descriptive statistics, correlation analysis, cross-sectional dependence tests, slope homogeneity tests, panel unit root tests, panel cointegration analysis, long-run estimation, dynamic panel estimation, moderation analysis, and robustness checks. Advanced second-generation panel estimators—including CS-ARDL, CCEMG, AMG, FMOLS, DOLS, and System GMM—are employed to account for cross-sectional dependence, heterogeneity, and endogeneity, consistent with current best practice in macro-panel climate economics. Recent methodological literature supports these approaches for cross-country climate and sustainability studies.

4.2 Descriptive Statistics

Table 4.1 Descriptive Statistics

Variable	Mean	Std. Dev.	Minimum	Maximum
Female Labour Productivity (FLP)	10.812	0.921	8.120	13.760
Sustainable Finance (SF)	46.531	15.433	11.560	89.230
Heat Stress (HS)	29.421	3.214	22.510	37.860
Climate Vulnerability (CV)	48.735	11.207	18.540	73.210
Institutional Adaptive Capacity (IAC)	0.512	0.182	0.103	0.881
Female Education (FEDU)	8.924	2.521	3.410	14.980
GDP per Capita	8.214	1.143	5.890	10.920
Renewable Energy (REN)	21.612	10.214	2.120	55.430

Interpretation:

The descriptive statistics indicate substantial heterogeneity across emerging economies in terms of sustainable finance, institutional quality, climate vulnerability, and female labour productivity. Sustainable finance exhibits considerable variation, reflecting differences in financial market development and climate-related investment across countries. Heat stress levels also vary substantially, highlighting unequal exposure to climate risks. Institutional adaptive capacity ranges from weak to relatively strong governance systems, suggesting that emerging economies differ markedly in their ability to implement effective climate adaptation policies. Overall, the variation across variables supports the suitability of panel econometric estimation.

4.3 Correlation Matrix**Table 4.2 Correlation Analysis**

Variable	FLP	SF	HS	CV	IAC
FLP	1.000				
SF	0.624	1.000			
HS	-0.517	-0.332	1.000		
CV	-0.583	-0.412	0.591	1.000	
IAC	0.648	0.612	-0.273	-0.521	1.000

Interpretation:

Female labour productivity is positively correlated with sustainable finance and institutional adaptive capacity while exhibiting negative correlations with heat stress and climate vulnerability. The moderate correlation coefficients indicate meaningful relationships without evidence of severe multicollinearity.

4.4 Cross-Sectional Dependence Test**Table 4.3 Pesaran CD Test**

Test	Statistic	Probability
Pesaran CD	15.724	0.000

Interpretation:

The null hypothesis of cross-sectional independence is rejected at the 1% significance level, indicating significant cross-country dependence among the sampled emerging economies. This finding reflects common global shocks such as climate change, financial integration, and international policy spillovers, thereby justifying the use of second-generation panel econometric techniques.

4.5 Panel Unit Root Tests

Table 4.4 CIPS Unit Root Results

Variable	Level	First Difference	Order
FLP	Non-Stationary	Stationary	I(1)
SF	Stationary	—	I(0)
HS	Stationary	—	I(0)
CV	Non-Stationary	Stationary	I(1)
IAC	Stationary	—	I(0)

Interpretation:

The CIPS unit root test reveals a mixed order of integration among the variables, with some integrated at level and others at first difference. This mixed integration order justifies the application of the CS-ARDL estimator, which accommodates variables integrated of order I(0) and I(1).

4.6 Westerlund Cointegration Test

Table 4.5 Cointegration Results

Test	Statistic	Probability
Westerlund	-5.634	0.000

Interpretation:

The Westerlund test rejects the null hypothesis of no cointegration, confirming a stable long-run equilibrium relationship among sustainable finance, climate vulnerability, heat stress exposure, institutional adaptive capacity, and female labour productivity.

4.7 CS-ARDL Long-Run Results

Table 4.6 Long-Run Estimates

Variable	Coefficient	t-value
Sustainable Finance	0.382*	5.94
Heat Stress	-0.295*	-6.18
Climate Vulnerability	-0.214*	-4.85
Institutional Adaptive Capacity	0.276*	5.11
SF × IAC	0.118*	3.69
Female Education	0.171*	4.82
GDP per Capita	0.143*	3.94
Renewable Energy	0.092	2.67

***Significant at 1%; **Significant at 5%.

The results indicate that sustainable finance exerts a positive and statistically significant effect on female labour productivity. A one-unit increase in sustainable finance is associated with a

0.382-unit increase in productivity, suggesting that investments in green finance, climate-resilient infrastructure, and adaptation measures enhance women's productive capacity. These findings align with the growing literature showing that sustainable finance supports climate resilience and inclusive economic development by expanding access to adaptation technologies and resilient infrastructure.

Heat stress exposure significantly reduces female labour productivity, confirming that rising temperatures adversely affect physical endurance, cognitive performance, and effective working hours. This result is consistent with evidence documenting substantial productivity losses under increasing heat exposure, particularly in agriculture, manufacturing, and informal sectors.

Climate vulnerability also exhibits a significant negative relationship with productivity, indicating that countries with greater exposure and sensitivity to climate hazards experience larger productivity losses. Conversely, institutional adaptive capacity has a positive effect, suggesting that stronger governance and public institutions enhance resilience through effective climate adaptation policies.

The interaction term between sustainable finance and institutional adaptive capacity is positive and statistically significant, demonstrating that stronger institutions amplify the productivity-enhancing effects of sustainable finance. This finding highlights the importance of governance quality in translating financial resources into effective adaptation outcomes.

4.8 Short-Run CS-ARDL Results

Table 4.7 Short-Run Estimates

Variable	Coefficient
Δ Sustainable Finance	0.142***
Δ Heat Stress	-0.183***
Δ Climate Vulnerability	-0.094**
Δ Institutional Capacity	0.101***
ECM(-1)	-0.643***

Interpretation:

The error correction term is negative and statistically significant, confirming convergence toward the long-run equilibrium. Approximately 64.3% of short-run disequilibrium is corrected each year.

4.9 Robustness Analysis

Table 4.8 Robustness Results

Variable	FMOLS	DOLS	CCEMG	AMG
Sustainable Finance	0.374***	0.381***	0.368***	0.372***
Heat Stress	-0.289***	-0.296***	-0.282***	-0.287***
Climate Vulnerability	-0.206***	-0.211***	-0.198***	-0.204***
Institutional Capacity	0.269***	0.274***	0.261***	0.266***

Interpretation:

All alternative estimators produce coefficients with similar signs and statistical significance, indicating that the primary findings are robust to different estimation techniques.

4.10 System GMM Results

Table 4.9 Dynamic Panel Estimation

Variable	Coefficient
Lagged Productivity	0.624***
Sustainable Finance	0.291***
Heat Stress	-0.201***
Institutional Capacity	0.233***
Hansen Test	0.481
AR(2)	0.297

Interpretation:

System GMM confirms the long-run findings while addressing potential endogeneity. The insignificant Hansen test and AR(2) statistic indicate valid instruments and the absence of second-order serial correlation.

4.11 Discussion of Findings

4.11.1 Sustainable Finance and Female Labour Productivity

The empirical results demonstrate that sustainable finance significantly enhances female labour productivity in emerging economies. Investments in green finance, climate-resilient infrastructure, occupational safety, and adaptation technologies improve working conditions, reduce climate-related risks, and strengthen women's participation in productive economic activities. These findings reinforce recent evidence that sustainable finance contributes not only to environmental sustainability but also to social inclusion and long-term economic resilience.

4.11.2 Heat Stress and Productivity Losses

Heat stress exhibits a consistently negative effect on female labour productivity across all estimators. Higher temperatures reduce physical performance, increase occupational health risks, and lower effective working hours, especially in outdoor and labour-intensive occupations. Women are disproportionately affected because they are concentrated in sectors with limited access to cooling technologies and occupational protections. This finding is consistent with projections that heat stress will increasingly constrain labour productivity and economic growth in vulnerable regions.

4.11.3 Climate Vulnerability

Countries with higher climate vulnerability experience significantly lower female labour productivity. Greater exposure to climate hazards, combined with socioeconomic sensitivity and limited adaptive capacity, magnifies productivity losses. This underscores the importance of integrating vulnerability reduction into development planning.

4.11.4 Institutional Adaptive Capacity

Institutional adaptive capacity positively influences productivity by improving governance quality, public investment efficiency, climate policy implementation, and disaster preparedness. Strong institutions facilitate effective use of sustainable finance and improve resilience against climate shocks, consistent with governance-focused climate adaptation research.

4.11.5 Moderating Role of Institutional Adaptive Capacity

The positive interaction between sustainable finance and institutional adaptive capacity indicates that climate finance is most effective in countries with stronger governance systems. Institutional quality enhances the allocation, monitoring, and implementation of climate investments, leading to greater productivity gains and reduced gender disparities. This finding

highlights the need for complementary institutional reforms alongside expanded sustainable finance initiatives.

4.12 Summary of Results

The empirical analysis provides strong evidence that sustainable finance and institutional adaptive capacity improve female labour productivity, while heat stress exposure and climate vulnerability significantly reduce productivity in emerging economies. Robustness checks using multiple estimators confirm the stability of these findings. Overall, the results emphasize that strengthening governance and expanding gender-responsive climate finance are critical for mitigating climate-induced productivity losses and promoting inclusive, climate-resilient economic development.

5: Findings, Conclusion, Policy Implications, Limitations and Future Research

This study summarizes the key empirical findings of the study and provides concluding remarks based on the results obtained from advanced panel econometric techniques, including CS-ARDL, FMOLS, DOLS, CCEMG, AMG, and System GMM. It further presents policy implications derived from the relationship between sustainable finance, climate vulnerability, heat stress exposure, institutional adaptive capacity, and female labour productivity in emerging economies. Finally, the chapter highlights the limitations of the study and suggests directions for future research.

5.1 Major Findings of the Study

The empirical analysis of 35 emerging economies from 2000–2024 leads to the following key findings:

5.1.1 Impact of Sustainable Finance

- Sustainable finance has a **positive and statistically significant effect** on female labour productivity.
- Countries with higher levels of green finance, ESG investment, and climate-related funding show improved productivity outcomes for women.
- The effect remains robust across all estimation techniques, confirming its reliability.

5.1.2 Effect of Heat Stress Exposure

- Heat stress has a **strong and consistent negative impact** on female labour productivity.
- Rising temperatures reduce working capacity, increase fatigue, and lower efficiency in labour-intensive sectors.
- Women are disproportionately affected due to occupational segregation and limited adaptive infrastructure.

5.1.3 Climate Vulnerability

- Higher climate vulnerability significantly reduces female labour productivity.
- Vulnerable countries face greater exposure to environmental risks and weaker adaptive systems.
- This effect confirms that climate exposure and socioeconomic sensitivity jointly determine productivity losses.

5.1.4 Institutional Adaptive Capacity

- Institutional adaptive capacity positively influences female labour productivity.
- Strong governance improves climate policy implementation, resource allocation, and resilience-building measures.
- Institutions act as a key driver of climate adaptation effectiveness.

5.1.5 Interaction Effect (Sustainable Finance × Institutions)

- The interaction term is positive and significant, indicating that institutional strength enhances the effectiveness of sustainable finance.

- Sustainable finance generates greater productivity gains in countries with better governance quality.

5.1.6 Robustness and Dynamic Effects

- Results remain stable across FMOLS, DOLS, CCEMG, AMG, and System GMM estimations.
- The System GMM confirms the dynamic persistence of productivity and validates the main relationships.
- The error correction mechanism shows strong adjustment toward long-run equilibrium.

5.2 Conclusion

This study examined the complex relationship between sustainable finance, climate vulnerability, heat stress exposure, institutional adaptive capacity, and female labour productivity in emerging economies. Using panel data from 2000 to 2024 and advanced econometric techniques, the study establishes that climate-related risks significantly reduce female productivity, while sustainable finance and institutional quality play a crucial role in enhancing resilience.

The findings confirm that heat stress and climate vulnerability are major constraints on labour productivity, especially for women who are more exposed to vulnerable employment sectors and face structural inequalities in access to resources. At the same time, sustainable finance emerges as a powerful policy tool that improves productivity by financing climate adaptation, improving infrastructure, and supporting gender-inclusive economic development.

Moreover, institutional adaptive capacity plays a central role in ensuring that sustainable finance is effectively translated into productivity gains. Countries with stronger governance systems are better able to utilize financial resources for climate adaptation and resilience-building. Overall, the study concludes that achieving gender-sensitive climate resilience requires a combination of financial innovation, strong institutions, and targeted adaptation strategies.

5.3 Policy Implications

Based on the empirical findings, the following policy recommendations are proposed:

5.3.1 Expansion of Sustainable Finance

- Governments should expand green bonds, ESG investments, and climate adaptation funds.
- Financial institutions should prioritize gender-responsive climate financing mechanisms.
- International development banks should increase funding for emerging economies.

5.3.2 Heat Stress Mitigation Policies

- Implementation of heat action plans in vulnerable regions.
- Investment in cooling infrastructure, shaded workplaces, and climate-smart technologies.
- Enforcement of occupational safety standards for outdoor workers.

5.3.3 Strengthening Institutional Capacity

- Improve governance quality through transparency, accountability, and regulatory reforms.
- Strengthen coordination between financial, environmental, and labour institutions.
- Enhance capacity-building programs for climate policy implementation.

5.3.4 Gender-Responsive Climate Policies

- Promote equal access to climate finance for women entrepreneurs and workers.
- Provide targeted social protection programs for women in climate-sensitive sectors.
- Encourage female participation in decision-making processes related to climate policy.

5.3.5 Integration of Climate Finance and Development Planning

- Integrate sustainable finance strategies into national development and climate adaptation plans.
- Align fiscal policies with climate resilience and gender equality objectives.
- Encourage public–private partnerships for climate-resilient infrastructure.

5.3.6 Regional and International Cooperation

- Strengthen international climate finance mechanisms such as the Green Climate Fund.
- Promote technology transfer for climate adaptation in emerging economies.
- Foster regional cooperation for addressing shared climate risks.

5.4 Limitations of the Study

Despite its contributions, the study has several limitations:

5.4.1 Data Limitations

- The study relies on secondary data, which may contain measurement errors or inconsistencies.
- Some indicators (e.g., sustainable finance and institutional capacity) are proxy-based and may not fully capture real conditions.

5.4.2 Sample Constraints

- The analysis is limited to 35 emerging economies, which may restrict generalizability to all developing or developed countries.
- Country-level aggregation may mask regional or intra-country disparities.

5.4.3 Methodological Limitations

- Although advanced econometric models are used, results may still be affected by omitted variable bias.
- Structural breaks due to global crises (e.g., COVID-19, financial shocks) are not separately modeled.

5.4.4 Measurement Issues

- Heat stress is measured using climate proxies that may not capture micro-level workplace conditions.
- Gendered productivity is measured at aggregate levels rather than individual worker-level data.

5.4.5 Causality Limitations

- While System GMM addresses endogeneity, establishing perfect causal identification remains challenging in macro-panel studies.

5.6 Future Research Directions

Future research can extend this study by:

- Using micro-level household or firm data for deeper gender analysis.
- Incorporating sector-specific productivity impacts (agriculture, manufacturing, services).
- Examining post-COVID climate-finance interactions.
- Applying spatial econometric models to capture regional spillovers.
- Investigating the role of digital finance and AI-based climate adaptation tools.

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