Article

Not peer-reviewed version

Impact of Climate Change on Inflation in 26 Selected Countries

Cunpu Li , Xuetong Zhang , Jing He *

Posted Date: 1 August 2023

doi: 10.20944/preprints202308.0059.v1

Keywords: climate shocks; temperature change; inflation; monetary policy

Article

Impact of Climate Change on Inflation in 26 Selected Countries

Cunpu Li [1], Xuetong Zhang [1] and Jing He [2,*]

[1] School of Economics and Finance, Xi'an International Studies University, Xi'an 710128, China; licunpu@xisu.edu.cn; 1312593307@ qq.com
[2] Management School, Xi'an University of Architecture and Technology, Xi'an 710055, China
* Correspondence: 81305039@qq.com; Tel.: +13891939526

Abstract: In the era of persistent globalization, climate governance has emerged as a prominent concern within both the theoretical community and government departments of diverse nations. Of particular interest in academic research is the adverse effect of climate shocks on the global economy. This paper employs average temperature as a surrogate indicator for climate shocks and examines the influence of temperature fluctuations on inflation levels using a balanced panel dataset from 1995 to 2021. The findings indicate a positive association between temperature change and inflation within the country, which remains consistent even after subjecting the analysis to multiple robustness tests. Furthermore, accounting for heterogeneity reveals variations in the magnitude of response of inflation levels to temperature fluctuations. Regarding the analysis of underlying mechanisms, the study underscores the significance of energy demand as a pivotal pathway influencing inflationary pressures at the national level. Lastly, by incorporating GDP per capita as a threshold, the research reveals a nonlinear relationship between temperature change and inflation levels.

Keywords: climate shocks; temperature change; inflation; monetary policy

---

1. Introduction

The increasingly frequent occurrence of extreme natural disasters and global temperature anomalies have elevated climate shocks to a significant impediment to both human survival and development[1]. In January 2023, the Global Risks Report 2023 by the World Economic Forum (WEF) provided rankings of global risks in terms of severity, encompassing both the short-term (next two years) and long-term (next ten years) outlook. Furthermore, in March 2023, the Intergovernmental Panel on Climate Change (IPCC) of the United Nations released its sixth assessment report (AR6), highlighting the role of anthropogenic greenhouse gas emissions in driving global warming. The report underscores the extensive ramifications on food and water security, and human health, as well as the far-reaching economic, social, and environmental development as the three pillars of sustainability. In April 2023, the Emergency Disaster Database (EM-DAT) reported that the cumulative economic losses attributed to climate change reached a staggering $223.8 billion. The year 2022 witnessed the occurrence of 387 natural disasters worldwide, leading to a tragic loss of 30,704 lives and affecting approximately 185 million individuals. Notably, hot weather conditions alone accounted for 16,305 fatalities, constituting over half of the total deaths recorded in 2022.

Climate change is a pressing global issue that poses significant challenges to the development of nations worldwide. Temperature change has consistently garnered substantial attention from countries across the globe. An example of this attention is the 26th Conference of the Parties (COP26) of the United Nations Framework Convention on Climate Change (UNFCCC) in November 2021. At this conference, 200 countries and major economies signed the Glasgow Climate Convention. They committed to limiting global warming to 1.5 degrees Celsius (currently approaching 1.2 degrees Celsius) to mitigate the escalation of extreme catastrophic climate events on a global scale. Global warming serves as a critical manifestation of climate change, with temperature change serving as a crucial indicator thereof. Against this backdrop, scholars and experts have delved into the multifaceted impact of temperature change on crucial aspects such as human life security, economic development, financial stability, agricultural production, energy consumption, and ecosystems.

 doi:10.20944/preprints202308.0059.v1

Inflation, a key macroeconomic factor, holds a pivotal role in the monetary policy objectives of central banks and serves as a measure of a country's economic health and smooth progress. Not only is it a matter of utmost concern for government departments worldwide, but it also assumes great importance for citizens, directly influencing their living standards and well-being. The awareness has increased steadily among scholars regarding the impact of temperature changes, within the framework of climate shocks, on the level of inflation[2–7]. Prior research has demonstrated the significant impact of temperature changes on the level of inflation within a country, with the magnitude of this effect varying across nations with different levels of economic development. Notably, Faccia et al.[5]discovered that abnormal summer temperatures exert distinct influences on inflation levels in developed and developing countries. Specifically, high summer temperatures were found to decrease inflation in the medium to long-term in developed countries. Conversely, Mukherjee et al.[7] revealed that temperature shocks induce inflationary pressures in both developed and developing countries, with the effects persisting for a longer duration in developing nations.

Hence, this paper adopts the relationship between climate change and inflation as a focal point, conducting empirical analyses to investigate the impact of temperature changes resulting from climate shocks on inflation. This investigation utilizes balanced panel data encompassing 26 selected countries from 1995 to 2021 to formulate policy recommendations aimed at addressing the identified issues.

According to the World Meteorological Organization (WMO), climate change refers to the alteration in average weather patterns over an extended duration. The IPCC of the United Nations defines climate change as the application of statistical analyses to detect alterations in the mean or rate of change in pertinent data, thereby identifying shifts in the climate state that persist for decades or longer. Additionally, the UNFCCC defines climate change as modifications in the global climate system over an extended timeframe, attributed directly or indirectly to human activities.

In empirical analyses aimed at measuring climate change, certain scholars utilize temperature change as a key metric [8–13]. Some scholars utilize greenhouse gas emissions as a metric to assess changes in the climate over a specific time frame[14]. In contrast, other scholars employ the frequency of extreme natural disasters recorded in the Emergency Disaster Database (EM-DAT) as an indicator to measure climate change[15–17]. In recent years, climate change has attracted significant attention from researchers. The frequency of extreme natural disasters and the associated economic losses resulting from abnormal temperatures have been on the rise worldwide. Consequently, an increasing number of scholars have dedicated their efforts to investigating the interconnection between climate change and various aspects such as economic development, financial stability, human life security, agricultural production, and energy consumption.

Previous studies have demonstrated the adverse effects of temperature changes and extreme natural disasters on macroeconomic factors. For instance, Bansal and Ochoa [8] conducted an analysis using global capital market data and revealed that the covariance between country stock returns and temperature carries valuable information regarding cross-country risk premiums. They further highlighted the influence of temperature on the overall economy, with the temperature risk premium being more pronounced in countries situated closer to the equator. Similarly, Hsiang and Jina [18] investigated the impact of natural disasters on national economic growth, shedding light on the repercussions of such events on economic development. Following natural disasters, there is a notable decline in national income, and the recovery process can extend over 20 years. Nordhaus [19] employs an updated DICE model to project the uncertainty surrounding future climate change, highlighting the highly uncertain nature of the impact of climate change on future economic variables. Additionally, Luo Liangwen[20] extensively reviews the literature on the impacts of climate change on economic growth, agriculture, and labor markets. The findings indicate substantial economic losses resulting from these impacts, particularly in developing countries. Debelle [21] pointed out that natural disasters caused by climate change can increase infrastructural damages, agricultural losses, and product prices. Yang Lu[22]examined the impact of temperature changes on China's industrial output using firm-level microdata to predict the medium- and long-term effects of future warming. The findings revealed that temperature changes are likely to result in a decline in China's industrial output. Yang X X [23] developed a long-term dynamic change output model to analyze the adverse impacts of climate shocks, specifically warming, on economic and financial development. Feitelson et al. [24] demonstrated the role of climate change as an intermediary factor contributing to violent conflicts in the Middle East. Pugatch T[25] discovered a positive correlation between extreme weather events, specifically storms, and mortality rates in Mexico. The mortality rate is found to be influenced by the balance between intensity and frequency of storms. The agricultural sector is currently facing its most significant threat from climate change, as it gives rise to natural disasters that pose substantial risks to agricultural production. Research indicates that both temperature anomalies and precipitation can adversely affect agricultural yields. Lei X[26] employed a dynamic stochastic general equilibrium model to assess the quantitative repercussions of climate change on China's macroeconomy. The findings indicate that climate change will have a detrimental effect on the output value of the agricultural sector and impose higher welfare costs on households. Mukherjee and Ouatarra [7] highlighted the influence of temperature fluctuations on agricultural production and energy demand. They further emphasized that when the demand surpasses the supply, the price levels increase globally. Liu M H[10] examined the impact of temperature change on household energy consumption, specifically from the perspective of demand heterogeneity, using panel data.

To date, researchers have conducted comprehensive investigations into the influence of climate change on macroeconomic factors from multiple perspectives. However, there has been relatively less emphasis on exploring the specific effects of temperature changes and extreme natural disasters on inflation. Moreover, scholarly consensus has not been reached regarding the relationship between climate change and inflation, with diverging viewpoints among scholars. Some argue that climate change has an insignificant impact on inflation levels. For example, Cavallo et al.[27] show that this relationship is insignificant in Chile in 2010. Abe [28] observed that Japan experienced a minimal increase in inflation following the disaster. However, certain scholars argue that climate does indeed affect inflation. From a supply perspective, climate change can stimulate inflation growth. Temperature anomalies and frequent natural disasters can adversely impact agricultural production and infrastructure, leading to detrimental supply shocks [29]. Heinen et al [3] revealed that floods and hurricanes are considerably effective in inflation in 15 Caribbean countries. Also, Batten et al. [4]found that temperature changes contribute to increased volatility in agricultural and energy prices, subsequently leading to heightened volatility in inflation levels. Similarly, Klomp and Sseruyange [6] discovered that natural disasters have a substantial impact on raising the price level of a country, regardless of the independence of the central bank. From a demand perspective, the reconstruction of damaged infrastructure may contribute to inflationary pressures. Mukherjee and Ouatarra [7] utilized a PVAR model to examine the effect of temperature shocks on inflation and found that such shocks create inflationary pressures in both developed and developing countries. Furthermore, the effects of temperature shocks tend to last longer in developing countries. Conversely, other scholars contend that climate change reduces inflation. Doyle and Noy [2] conducted an empirical analysis on the economy of New Zealand in short-term using a VAR model, specifically examining the impact of natural disasters. Their findings indicated that the occurrence of natural disasters reduces the overall demand within the country, subsequently leading to a decrease in the level of inflation. Faccia et al.[5] investigated the influence of abnormal summer temperatures on inflation in developed and developing countries. Their findings revealed that high summer temperatures lead to a decrease in inflation over the medium- to long-term. Additionally, the impact of significant natural disasters on inflation varies based on factors such as the country's level of development, the type and severity of the disaster, and the composition of inflation.

The literature review shows the considerable attention of researchers to the issue of climate change around the world, which has the following characteristics. Firstly, these studies mostly focus on the impact of climate change on economic development, financial stability, and human life security, while fewer studies target the analysis of the impact of climate change on inflation. Secondly, the existing studies have empirically examined the role of income level in the effect of climate change on inflation, which makes it difficult to identify the possible non-linear effects. To resolve these limitations, this paper focuses on the nexus of climate change and inflation and tries to expand the existing studies in the following aspects: 1- investigating the impact of climate change on inflation in a targeted manner; 2- using a panel threshold model to analyze the nonlinear role played by the high and low-income levels among countries in the effect of temperature change on inflation; and 3- using a panel mediation model to start from the demand side and explore the channels of the role of energy demand in the effect of temperature change on inflation.

2. Materials and Methods

2.1. Measurement model setting

2.1.1. Baseline regression model setting

To investigate the impact of climate change on inflation across various countries, this study utilizes balanced panel data encompassing 26 countries worldwide from 1995 to 2021. A panel two-way fixed effects model addresses the potential estimation bias caused by omitted variables. Equation 1 minimizes and eliminates such bias.

$$Inflation_{it} = \alpha_0 + \alpha_1 Tempworld_{it} + \alpha_3 Controls_{it} + \lambda_i + \lambda_t + \varepsilon_{it} \quad (1)$$

where i and t denote country and year, respectively. inflation and Tempworld are the explanatory and core explanatory variables, denoting the level of inflation and average temperature, respectively. The control variables mainly include urbanization rate (Urban), precipitation (PRE), GDP per capita ($GDPpercapita$), unemployment rate (Unemp), and money supply (M2). λ_i and λ_t denote country and time-fixed effects, respectively, and ε_{it} is random error terms. α_0 is the constant term; α_1 is the coefficient of temperature variation, representing the effect of climate factors on inflation.

2.1.2. Panel threshold Model setting

An econometric linear model may not effectively capture the complexities of the potential nonlinear effects of temperature changes on the relationship between inflation and GDP per capita. To address this issue, an econometrics threshold model accounts for changes in the direction or magnitude of economic parameter estimates when the parameter surpasses a specific threshold [30](Zhu Congmou 2020). By employing threshold regression, researchers can mitigate the issues arising from subjective judgment, thereby reducing statistical errors and estimation bias[31] (HOU Mengyang 2018). Based on the panel threshold model proposed by Hansen [32], this research estimates equation 2 which is a single threshold model.

$$Inflation_{it} = \beta_0 + \beta_1 Tempworld_{it} \times I(GDPpercapita_{it} \leq \theta) + \beta_2 Tempworld_{it} \times I(GDPpercapita_{it} > \theta) + \beta_3 Controls_{it} + \lambda_i + \lambda_t + \varepsilon_{it} \quad (2)$$

where GDP per capita is the threshold variable and I(-) is an indicator function that is equal to 0 when the expression in parentheses is false; otherwise, it is 1. The model is equivalent to a segmentation function that is equal to 1 when $GDPpercapita_{it} \leq \theta$ when $Tempworld_{it}$ the estimated coefficient of β_1; when$GDPpercapita_{it} > \theta$ when $Tempworld_{it}$ the estimated coefficients of β_2 and β_1 is not equal to β_2 are not equal, implying that there is a threshold effect of GDP per capita on inflation and that there is a difference in the effect of differences in GDP per capita on inflation.

After verifying the single threshold, the existence of multiple dual thresholds or multiple thresholds is further tested, and the dual threshold model is as follows:

$$Inflation_{it} = \beta_0 + \beta_1 Tempworld_{it} \times I(GDPpercapita_{it} \leq \theta_1) + \beta_2 Tempworld_{it} \times I(\theta_1 < GDPpercapita_{it} \leq \theta_2) + \beta_3 Tempworld_{it} \times I(GDPpercapita_{it} > \theta_2) + \beta_4 Controls_{it} + \lambda_i + \lambda_t + \varepsilon_{it} \quad (3)$$

where θ_1 and θ_2 are the first and second threshold values, respectively.

2.1.3. Intermediate effect model

In order to delve deeper into the mechanism through which temperature change affects inflation and to investigate the potential transmission pathway of "temperature change-energy consumption-inflation," this study establishes a mediating effect model. The model is built upon the baseline regression model and adopts the methodology introduced by Zhonglin Wen et al.[33]. Equations 4-6 show the mediating effect model.

$$Inflation_{it} = \alpha_0 + \alpha_1 Tempworld_{it} + \alpha_3 Controls_{it} + \lambda_i + \lambda_t + \varepsilon_{it} \quad (4)$$

$$lnEC_{it} = \beta_0 + \beta_1 Tempworld_{it} + \beta_3 Controls_{it} + \lambda_i + \lambda_t + \varepsilon_{it} \quad (5)$$

$$Inflation_{it} = \gamma_0 + \gamma_1 Tempworld_{it} + \gamma_2 lnEC_{it} + \gamma_3 controls_{it} + \lambda_i + \lambda_t + \varepsilon_{it} \quad (6)$$

where $lnEC_{it}$ is the mediating variable, measured by primary energy consumption. α_1, β_1, γ_1, and γ_2 are the core coefficients to focus on the mechanism analysis, when α_1、γ_2、β_1 are significant. γ_1 is insignificant, when energy consumption plays a partially mediating role in the effect of temperature on inflation. If the coefficients of $\alpha_1, \beta_1, \gamma_1$, and γ_2 are significant, energy consumption plays a fully mediating role. α_1 and γ_1 are total and direct effects of temperature change on inflation, respectively. $\beta_1 \times \gamma_2$ represents the mediating effect.

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 1 August 2023 doi:10.20944/preprints202308.0059.v1

2.2. Variable description

2.2.1. Explanatory variables

The inflation rate is the level of inflation within a country, a crucial indicator representing the monetary policy objectives of central banks. This study adopts the approach of Ruqing Wei [34] by employing two explanatory variables, namely the inflation rate (Inflation) and the annual growth rate of the GDP deflator (GDP deflator). The consumer price index (CPI) is utilized to measure inflation, representing the annual percentage change in the cost of a basket of goods and services typically purchased by the average consumer. In addition, the annual growth rate of the GDP deflator is employed as an alternative measure of inflation, providing a more comprehensive reflection of the overall price changes within the economy.

2.2.2. Core explanatory variables

Scholars commonly adopt average temperature and temperature change as indicators of climate change[8–13]. In this study, the average temperature (Tempworld) is the proxy for climate change. According to the literature review, climatic factors such as relative humidity and sunshine duration have a limited impact on inflation and are not incorporated into the current model due to data unavailability. Furthermore, for robustness testing, this paper includes temperature change (TEMPFAO) as an additional variable. To ensure the robustness of the analysis, the standardized annual average temperature (STEMP) serves as a proxy for average temperature, following the approach employed by Liu Bo [13].

2.2.3. Intermediate variables

Mukherjee and Ouatarra [7] have highlighted that global temperature change leads to an increase in energy demand. When this demand surpasses the available energy supply, it impacts the level of inflation and results in fluctuations in global price levels. Based on this analysis, this study considers energy consumption as the mediating variable to investigate the mechanism through which temperature change affects inflation. The utilization of global energy consumption data allows for an examination of energy consumption patterns across various countries worldwide.

3.2.4. Control variables

Inflation, as a significant indicator in macroeconomic analysis, is subject to the influence of various factors. This paper suggests incorporating control variables including the urbanization rate (Urban), GDP per capita (GDP-percapita), unemployment rate (Unemp), and money supply (M2). Specifically, the urbanization rate (Urban) has a direct effect on the consumption levels and preferences of residents, thereby exerting an impact on inflation. In this research, urbanization is the level of urbanization population divided by the total population.

Money supply (M2) as the quantity of money in circulation is another factor that influences inflation. GDP per capita (GDP-percapita) as the level of economic development is a significant determinant of inflation. GDP per capita in constant 2015 U.S. dollars is the proxy for economic development. Unemployment rate (Unemp) shows the level of unemployment. The unemployment rate is measured by the proportion of the unemployed population in the total labor force, paving the way for illustrating the Phillips curve which interconnects unemployment and inflation. Additionally, annual rainfall (PRE) is a control variable to consider the impact of annual rainfall on climate change alongside average temperature.

Table 1. Definition of variables

Symbol	Variable	Meaning
Inflation	Inflation	Inflation, as measured by the Consumer Price Index, reflecting the annual percentage change in the cost of a basket of goods and services purchased by the average consumer
GDP deflator	GDP deflator annual growth rate	Inflation rate indicating the rate of price change in the economy as a whole

TEMPworld	Average temperature	Average annual temperature
STEMP	Average temperature	Standardized mean temperature
TEMPFAO	Temperature change	Mean surface change temperature over land
lnUrban	Urbanization rate	Logarithmic value of the share of urban population in the total population
lnPRE	Precipitation	Average annual precipitation
lnGDPperca~a	GDP per capita	Logarithm of GDP per capita in constant 2015 dollars
lnEMP	Unemployment rate	Logarithm of the unemployed population as a percentage of the labor force
lnM2	Broad money supply	Logarithmic value of broad money supply
lnEC	Energy consumption	Total primary energy consumption, primary energy includes raw coal, crude oil, natural gas, hydropower, and nuclear power

2.3. Data and descriptive statistics

Based on the global GDP rankings for 2021, this paper considers the top 33 countries or regions that collectively account for 90% of the total global GDP . Among them, this selects 26 countries, representing various regions: America (4 countries), Asia (8 countries), Oceania (1 country), and Europe (13 countries). They comprise 19 high-income countries and 7 low- and middle-income countries, ensuring a diverse sample. The econometric model uses balanced panel data spanning from 1995 to 2021 in logarithmic form to mitigate the impact of data heteroskedasticity and minimize estimation errors. The dataset sources are the CEIC, EPS, World Bank World Development Indicators, IFS, BP World Energy, and FAO Climate Database. In cases where certain data points were missing, interpolation techniques fill in the gaps. All data processing and calculations were conducted using Stata17 statistical software. Table 2 presents the descriptive statistics of each variable used in the analysis:

The mean value of inflation (Inflation) is 4.75, where the minimum value is -4.48 and the maximum value is 197.41, with a standard deviation of 12.03, indicating high overall volatility. The standard deviation of the mean temperature (TEMPworld) is 8.40, with large volatility. While the standard deviation of precipitation (lnPRE) is 0.65, which indicates that the overall volatility of precipitation is low.

Table 2. Results of descriptive statistics of variables

Variable	Sample size	Average	Standard deviation	Maximum	Minimum
Inflation	702	4.75	12.03	197.41	-4.48
GDPdeflator	702	5.09	12.08	144.01	-16.91
TEMPworld	702	11.85	8.40	26.95	-5.27
STEMP	702	0.00	1.00	1.80	-2.04
TEMPFAO	702	1.10	0.60	3.69	-0.79
lnUrban	702	4.27	0.26	4.59	3.28
lnPRE	702	6.67	0.65	8.10	4.43
lnGDPperca~a	702	9.95	1.08	11.40	6.43
lnEMP	702	1.84	0.46	3.26	0.53
lnM2	702	13.20	1.43	17.44	9.93
lnEC	702	1.83	1.22	5.06	-0.74

3. Results

3.1. Baseline regression results

Table 3 presents the results of the benchmark regression analysis investigating the impact of temperature change on inflation in a country (region). The empirical analysis was conducted using Stata17 software, and the results are reported in columns (1) and (3) of the table. These columns reflect the findings when controlling solely for two-way fixed effects in both the country (region) and time dimensions, excluding additional control variables. The estimated coefficient of the main explanatory variable TEMPworld is positive, but statistically insignificant. This result suggests that temperature change has a relatively low direct effect on a country (region), ignoring the other influential factors. To mitigate potential estimation bias stemming from omitted variables, control variables (i.e., money supply, GDP per capita, unemployment rate, precipitation, and urbanization rate) were included in columns (2) and (4) of the regression analysis. The results demonstrate that after accounting for these additional factors, the estimated coefficient of the core explanatory variable TEMPworld is positive and statistically significant at the 5% level. This suggests that temperature change has a significant and positive effect on the inflation level.

Table 3. Baseline regression results

Variable	(1) inflation	(2) inflation	(3) GDP deflator	(4) GDP deflator
TEMPworld	0.948	1.894**	1.031	1.791**
	(0.912)	(0.842)	(0.907)	(0.842)
lnUrban		24.95**		12.99
		(9.683)		(9.686)
lnPRE		-1.922		-0.976
		(3.232)		(3.233)
lnGDPpercapita		5.375		9.056**
		(3.951)		(3.952)
lnEMP		-5.951***		-6.330***
		(1.563)		(1.563)
lnM2		-16.60***		-16.45***
		(1.578)		(1.578)
Constant	8.761	68.01*	6.744	75.59**
	(10.62)	(38.03)	(10.56)	(38.04)
National fixed	Yes	Yes	Yes	Yes
Year fixed	Yes	Yes	Yes	Yes
Observations	702	702	702	702
R-squared	0.136	0.293	0.132	0.282
Number of ID	26	26	26	26

Note: The values in the parentheses are t- or Z-statistics. ***, **, * denote the statistical significance at 1%, 5%, and 10% levels, respectively.

Furthermore, examining the effect of temperature change requires considering the impact of other control variables. The estimated coefficients of the explanatory variable TEMPworld for both representations of the inflation level are 1.894 and 1.791. These coefficients indicate that a 1% change in temperature within a country (region) will lead to a corresponding increase in the inflation level

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 1 August 2023 doi:10.20944/preprints202308.0059.v1

by 0.0189% and 0.0179%, respectively. These findings highlight the positive relationship between temperature change and inflation in the country.

3.2. Threshold effect (double threshold) – GDP per capita

To further examine the potential nonlinear impact of temperature fluctuations on the inflation level in relation to GDP per capita, this study employs GDP per capita as the threshold variable and utilizes Hansen's [32] bootstrap self-help method to assess the presence of a threshold effect. The single, double, and triple threshold tests were performed sequentially using Stata17 statistical software, with 500 repetitions of the sampling process. Table 4 presents the results of the threshold effect tests. The analysis reveals that GDP per capita rejects the null hypotheses of no threshold and only one threshold at the 5% and 1% significance levels, respectively. However, it accepts the original hypothesis of the presence of two thresholds. This finding suggests the existence of a double threshold effect of GDP per capita in the relationship between temperature change and inflation.

Table 4. Results of the threshold effect test with GDP per capita as the threshold variable

Threshold test	Original hypothesis	F-value	P-value	Threshold		
				10%	5%	1%
Single Threshold	H_0: No threshold value	44.490	0.026	28.973	36.088	55.259
Double Threshold	H_0: A threshold value exists	113.67	0.000	12.315	15.373	21.032
Three thresholds	H_0: Two thresholds exist	11.240	0.680	138.243	153.626	197.605

Note: bootstrap repeated sampling 500 times, grid number 100, and 1% tailing. ***, **, * denote the statistical significance at 1%, 5%, and 10% levels, respectively.

Table 5 presents the results of the threshold model analysis. The findings indicate that the first threshold value of GDP per capita is estimated to be 5618.95, while the second threshold value is estimated to be 6524.5. Within the range of these threshold values, GDP per capita exhibits a significant and positive effect on the inflation level.

Table 5. Threshold estimation results.

Threshold variable	Number of thresholds	Threshold	95% confidence interval
GDP per capita	Single Threshold	5618.951	(4686.859, 6868.704)
	Double Threshold	6427.308	(6022.847, 6613.991)

Corresponding to Table 5, Figure 1 shows the test of the threshold estimation results.

As per the principle of the threshold model, the threshold estimate corresponds to the value at which the likelihood ratio (LR) statistic is closest to 0, representing the lowest point on the LR plot. The validity of the threshold estimate is confirmed when the LR associated with the estimated threshold is smaller than the critical value. In this case, all the lowest points on the graph are smaller than the critical value, confirming the validity of the threshold estimates. Table 6 shows the panel threshold estimation results.

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 1 August 2023 doi:10.20944/preprints202308.0059.v1

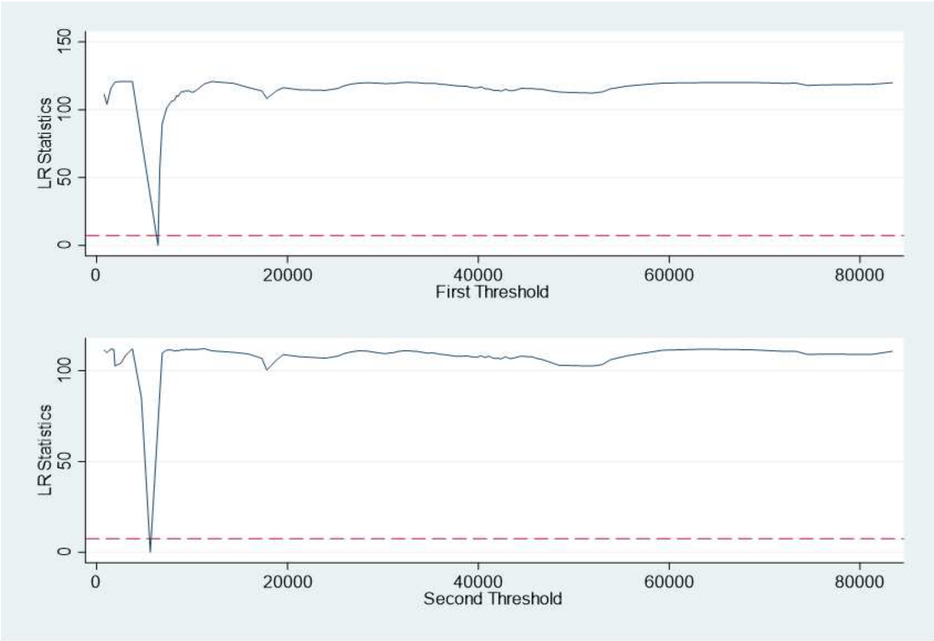

Figure 1. LR chart of GDP per capita threshold estimates

Table 6. Panel threshold estimation results

Variable	Estimated value
GDP per capita (GDP per capita ≤ 5618.951)	-0.548 (0.665)
GDP per capita (5618.951 < GDP per capita ≤ 6427.308)	5.049 (0.001)
GDP per capita (GDP per capita > 6427.308)	1.882 (0.225)
Control variables	Yes
National fixed	Yes
Time fixed	Yes
R^2	0.3345
N	702

Note: The values in the parentheses are t- or Z-statistics. ***, **, * denote the statistical significance at 1%, 5%, and 10% levels, respectively.

3.3. Mechanism test

Table 7 represents the regressions results to examine the existence of this transmission pathway. Column (1) of Table 7 displays the results of the total effect regression, indicating a direct and positive relationship between temperature change and the inflation level, which is statistically significant at 5% level. Column (2) shows whether temperature change impacts energy demand. The coefficient of average temperature is estimated to be -0.0295, which is statistically significant at 1% level. This suggests that a one-unit increase in average temperature leads to a 0.0295 percentage point decrease in energy demand. This paper argues that this decrease in energy consumption is attributed to the reduced utilization of non-clean energy sources during the country's development. Climate change has significant implications for global supply and demand dynamics. On the demand side, climate change contributes to a decline in consumer demand, investment, and trade activities. On the supply side, climate change results in reduced labor productivity and ultimately leads to a decrease in overall production capacity. The impact of temperature changes is twofold. Firstly, it reduces the demand for non-clean energy sources as individuals and industries shift towards cleaner alternatives. Secondly, it negatively affects labor productivity and increases transaction costs, thereby limiting the energy supply. The final price level relies on the relative changes in supply and demand resulting from these factors. The reduction in energy supply outweighs the reduction in energy demand,

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 1 August 2023 doi:10.20944/preprints202308.0059.v1

resulting in an overall increase in the price level. Column (3) shows whether energy consumption acts as a mediator between temperature change and inflation. The coefficient of energy consumption is 11.7676, which is statistically significant at 1% level. This finding suggests the presence of a mediating effect, with the regression coefficient of temperature change being significantly positive. This indicates that energy consumption partially mediates the relationship between temperature change and inflation, thereby confirming the existence of the "temperature change-energy consumption-inflation" pathway.

Table 7. Results of intermediate effect test

Variable	(1) inflation	(2) lnEC	(3) inflation
TEMPworld	1.8941**	-0.0295***	2.2413***
	(2.2492)	(-2.9630)	(2.6675)
lnEC			11.7676***
			(3.5636)
lnM2	-16.6006***	0.1647***	-18.5385***
	(-10.5199)	(8.8244)	(-11.1965)
lnPRE	-1.9215	-0.0583	-1.2351
	(-0.5946)	(-1.5262)	(-0.3849)
lnUrban	24.9546**	0.9791***	13.4335
	(2.5771)	(8.5496)	(1.3266)
lnGDPpercapita	5.3751	0.3496***	1.2608
	(1.3606)	(7.4835)	(0.3089)
lnEMP	-5.9506***	0.0725***	-6.8036***
	(-3.8084)	(3.9226)	(-4.3421)
National fixed	Yes	Yes	Yes
Year Fixed	Yes	Yes	Yes
_cons	68.0125*	-7.3106***	154.0407***
	(1.7886)	(-16.2569)	(3.4419)
N	702	702	702
R2	0.2928	0.7036	0.3065

Note: The values in the parentheses are t- or Z-statistics. ***, **, * denote the statistical significance at 1%, 5%, and 10% levels, respectively.

To ensure the robustness of the results, this study employs the bootstrap test to examine the mediation effect of energy consumption on the original sample of 1000 observations. The bootstrap test results in Table 8 reveal that the confidence interval of the indirect effect excludes 0. This finding suggests the presence of an indirect effect of temperature change on inflation, with energy consumption serving as a mediating variable. Furthermore, the confidence interval of the direct effect also excludes 0, indicating the existence of a direct effect of temperature change on inflation. In this context, energy consumption demonstrates a partial mediating role.

Table 8. Estimated mediating effects of energy consumption (bootstrap method)

Type of effect	Coefficient	Standard error	95% confidence interval	
			Lower limit	Upper limit
Indirect_bs_1	-0.091***	0.035	-0.159	-0.022
Direct_bs_2	-0.243***	0.088	-0.417	-0.070

3.4. Robustness test

3.4.1. Substitution of explanatory variables

Robustness tests use three distinct methodologies to check the robustness of the benchmark regression results. Table 9 represents the robustness tests results.

In the subsequent analysis, the key explanatory variables are substituted. Specifically, this study re-conducts the regression using temperature change data sourced from the UN FAO climate database (TEMPFAO) and follows the approach employed by Liu Bo [13] using standardized annual average temperature (STEMP) as a proxy for average temperature. Table 9 presents the regression results. Following the replacement of the core explanatory variables, the positive effect of temperature change on inflation persists due to its statistically significant effect. Notably, the findings regarding the core explanatory variables align with the results obtained from the benchmark regression on the full sample. This consistency indicates the robustness of the test outcomes, even after replacing the core explanatory variables.

Table 9. Robustness test results for replacing explanatory variables

Variable	(1) inflation	(2) GDP deflator	(3) inflation	(4) GDP deflator
TEMPFAO	1.407*	1.771**		
	(0.855)	(0.854)		
STEMP			15.90**	15.03**
			(7.068)	(7.070)
lnUrban	22.26**	10.36	24.95**	12.99
	(9.640)	(9.627)	(9.683)	(9.686)
lnPRE	-2.119	-1.140	-1.922	-0.976
	(3.236)	(3.231)	(3.232)	(3.233)
lnGDPpercapita	6.323	10.21**	5.375	9.056**
	(3.988)	(3.983)	(3.951)	(3.952)
lnEMP	-5.920***	-6.248***	-5.951***	-6.330***
	(1.567)	(1.565)	(1.563)	(1.563)
lnM2	-16.79***	-16.79***	-16.60***	-16.45***
	(1.604)	(1.602)	(1.578)	(1.578)
Constant	94.31***	99.61***	90.46**	96.81***
	(35.88)	(35.83)	(35.89)	(35.90)
_cons	702	702	702	702
National fixed	Yes	Yes	Yes	Yes
Year Fixed	Yes	Yes	Yes	Yes
R-squared	0.290	0.281	0.293	0.282
N	26	26	26	26

Note: The values in the parentheses are t- or Z-statistics. ***, **, * denote the statistical significance at 1%, 5%, and 10% levels, respectively.

3.4.2. Adjust the research year interval

To consider the impact of special events on the research timeframe, the research adjusts the year interval, specifically regarding the Asian financial crisis in 1997 and the global financial crisis in 2008. These crises may have influenced the data on inflation and the unemployment rate during the respective periods. To address this issue, this study adopts a similar approach as Yuan Yiren[35], which excludes data from the original sample for the year in which the special event occurred, as well as the current and subsequent years. Then, this adjusted dataset revalidates the findings. Columns (1) and (2) present the regression results obtained after excluding only the year in which the special event occurred. In addition, columns (3) and (4) display the regression results obtained after excluding both the current and subsequent years. This approach considers the possibility that the special event may have a sustained impact on the economy beyond the year of its occurrence. Table 10 represents the results of these regressions. Even after excluding the special year, the analysis reveals a consistent positive effect of temperature change on inflation. These findings align with the test results obtained from the benchmark regression on the full sample. Moreover, all of the reported coefficients are statistically significant at 10% level, indicating the robustness of the findings.

Table 10. Robustness test results for replacing explanatory variables

Variables	(1) inflation	(2) GDP deflator	(3) inflation	(4) GDP eflator
TEMPworld	2.360***	2.164**	2.200**	1.891**
	(0.874)	(0.880)	(0.896)	(0.772)
lnUrban	27.32***	14.26	34.30***	23.06**
	(10.31)	(10.37)	(10.60)	(9.126)
lnPRE	-2.431	-1.414	-2.910	-2.652
	(3.392)	(3.414)	(3.468)	(2.987)
lnGDPpercapita	3.750	7.696*	2.971	6.330*
	(4.170)	(4.197)	(4.295)	(3.699)
lnEMP	-5.463***	-5.953***	-4.617***	-4.489***
	(1.620)	(1.631)	(1.645)	(1.417)
lnM2	-16.06***	-15.92***	-16.39***	-15.53***
	(1.645)	(1.656)	(1.721)	(1.483)
Constant	64.24	74.76*	49.78	54.72
	(40.20)	(40.46)	(40.88)	(35.21)
National fixed	Yes	Yes	Yes	Yes
Year Fixed	Yes	Yes	Yes	Yes
Observations	650	650	598	598
R-squared	0.294	0.279	0.302	0.332
Number of ID	26	26	26	26

Note: The values in the parentheses are t- or Z-statistics. ***, **, * denote the statistical significance at 1%, 5%, and 10% levels, respectively.

3.4.3. Excluded hyperinflationary countries

Furthermore, this study checks outliers and excludes countries with the experience of hyperinflation from the sample to ensure the robustness of the analysis[7]. Among the 26 countries considered in this study, four countries have experienced hyperinflation. Table 11 represents the outcomes of the re-test conducted after the exclusion. The analysis reveals that temperature change continues to exhibit a positive, which is statistically significant at 10% and 5%, respectively. These results indicate the robustness of the results.

Table 11. Robustness test results after excluding countries with experience of hyperinflationary

Variable	(1) inflation	(2) GDP deflator
TEMPworld	0.600*	0.933**

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 1 August 2023 doi:10.20944/preprints202308.0059.v1

	(0.339)	(0.465)
lnUrban	-8.972**	-11.27**
	(3.897)	(5.338)
lnPRE	-0.981	-0.479
	(1.217)	(1.667)
lnGDPpercapita	2.338	4.491**
	(1.593)	(2.183)
lnEMP	-0.972	-1.113
	(0.644)	(0.883)
lnM2	-1.024	-2.737***
	(0.757)	(1.038)
Constant	34.79**	37.69*
	(14.27)	(19.54)
National fixed	Yes	Yes
Year Fixed	Yes	Yes
Observations	594	594
R-squared	0.159	0.133
Number of ID	22	22

Note: The values in the parentheses are t- or Z-statistics. ***, **, * denote the statistical significance at 1%, 5%, and 10% levels, respectively.

3.5. Heterogeneity test

3.5.1. Income grouping – high-income and lower-middle-income country groupings

Research has demonstrated that the impact of climate shocks differs among countries at different stages of economic development. Developing countries, in particular, exhibit higher vulnerability to climate shocks, characterized by both greater intensity and longer durations of adverse effects, in contrast to developed countries [5,7]. Hence, in order to further examine the potential variations in the effects of temperature changes on inflation across countries with distinct income levels, this study conducts a classification test on the sample. Following the World Bank's classification criteria, countries can be categorized based on their income levels. Specifically, countries with a Gross National Income (GNI) per capita exceeding $13,205 in 2021 are classified as high-income countries, while those below this threshold are considered low- and middle-income countries. Based on the World Bank's income classification criteria, there are 19 high-income countries and 7 low- and middle-income countries.

Table 12 provides the regression results. Columns (1) and (2) show that average temperature change has a statistically insignificant effect on inflation in high-income countries. However, columns (3) and (4) show that the coefficients of average temperature change are 8.903 and 7.047, which are statistically significant at 1% and 5% levels, respectively. This result indicates heterogeneity in the effect of average temperature change on inflation across countries with different income levels. Specifically, low- and middle-income countries demonstrate higher vulnerability when confronted with climate shocks compared to high-income countries. Price stability is a vital prerequisite for boosting economic growth. However, in the face of external shocks, the timely identification and appropriate adjustment by central banks become crucial for ensuring the seamless operation of the economy. When central banks prioritize the assessment of climate change's impact on monetary policy, they enhance their ability to promptly discern the origins of inflationary pressures and implement effective measures to mitigate the adverse consequences of external shocks on the economy. By proactively addressing the influence of climate change on monetary policy, a country's

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 1 August 2023 doi:10.20944/preprints202308.0059.v1

central bank can swiftly identify the sources of inflationary pressures and implement appropriate measures to mitigate the negative impacts of external shocks on its economy.

For instance, according to Taylor's Law, central banks can respond to fluctuations in inflation or output by modifying short-term interest rates. Compared to high-income countries, low- and middle-income countries may have a relatively lower focus on climate-related issues and may exhibit reduced sensitivity in identifying inflationary pressures. Consequently, inflation levels in these countries may experience more pronounced fluctuations.

Table 12. Results of heterogeneity test in high-income versus lower- and middle-income countries

Variable	High-income countries		Low- and middle-income countries	
	(1) inflation	(2)GDP eflator	(3) inflation	(4) GDP deflator
TEMPworld	-0.213	0.0699	8.903***	7.047**
	(0.188)	(0.343)	(3.066)	(3.043)
lnUrban	6.526*	-2.351	100.2***	56.86*
	(3.669)	(6.684)	(29.84)	(29.62)
lnPRE	-0.660	-0.364	-4.314	-0.0287
	(0.678)	(1.236)	(14.93)	(14.82)
lnGDPpercapita	-6.281***	-5.548***	15.69	31.69**
	(1.044)	(1.903)	(13.35)	(13.24)
lnEMP	-1.617***	-2.067***	-19.47***	-20.76***
	(0.354)	(0.646)	(5.526)	(5.484)
lnM2	-1.752***	-3.858***	-27.30***	-27.66***
	(0.459)	(0.837)	(4.301)	(4.268)
Constant	72.30***	125.6***	-217.1	-174.1
	(22.13)	(40.31)	(132.8)	(131.8)
National fixed	Yes	Yes	Yes	Yes
Year Fixed	Yes	Yes	Yes	Yes
Observations	513	513	189	189
R-squared	0.342	0.189	0.613	0.592
Number of ID	19	19	7	7

Note: The values in the parentheses are t- or Z-statistics. ***, **, * denote the statistical significance at 1%, 5%, and 10% levels, respectively.

3.5.2. Temperature grouping (high-temperature group and low-temperature group

Using the median annual mean temperature as the cut-off point, the research is re-run for the high-temperature group and the low-temperature group , including countries with annual mean temperatures above the median mean temperature and vice versa. Table 13 shows the results. Columns (1) and (2) show that the change in average temperature has an insignificant effect on inflation in countries with high-temperature. The estimated coefficients are 3.175 and 2.125, statistically significant at 1% and 5% levels, respectively. Columns (3) and (4) show that this effect is positive and significant in countries with low-temperature groups.

This paper postulates that the observed variations can be attributed to the adaptive behavior of the climate. In contrast to the high-temperature group, countries in the low-temperature group may exhibit lower adaptability to temperature rises resulting from climate change, leading to reduced heat resistance among their residents. As the average temperature increases, there is a corresponding rise in the demand for cooling equipment to achieve physical comfort. However, if the rate of supply

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 1 August 2023 doi:10.20944/preprints202308.0059.v1

growth fails to match the rate of demand increase, it has implications for market prices. Consequently, this price dynamics can drive up prices and subsequently impact the inflation level. Therefore, the low-temperature group is more susceptible to the impacts of temperature changes compared to the high-temperature group.

Table 13. Results of heterogeneity test in high-temperature group versus low-temperature group

Variable	High-temperature group		Low-temperature group	
	(1) inflation	(2)GDP deflator	(3) inflation	(4) GDP deflator
TEMPworld	-0.267	0.951	3.175***	2.125**
	(1.368)	(1.754)	(1.224)	(0.925)
lnUrban	-49.88***	-61.86***	64.39***	50.48***
	(13.58)	(17.42)	(14.94)	(11.30)
lnPRE	0.404	2.980	-3.017	-1.711
	(3.566)	(4.574)	(6.873)	(5.196)
lnGDPpercapita	8.711*	13.07**	1.998	1.249
	(4.726)	(6.062)	(6.872)	(5.195)
lnEMP	-9.452***	-11.38***	-4.818*	-3.567*
	(1.861)	(2.387)	(2.603)	(1.968)
lnM2	-17.79***	-20.34***	-18.76***	-14.71***
	(1.905)	(2.444)	(2.679)	(2.025)
Constant	382.3***	389.9***	-26.75	-20.58
	(63.14)	(80.98)	(59.49)	(44.98)
Observations	351	351	351	351
R-squared	0.443	0.388	0.304	0.326
Number of ID	13	13	13	13

Note: The values in the parentheses are t- or Z-statistics. ***, **, * denote the statistical significance at 1%, 5%, and 10% levels, respectively.

4. Conclusions

This study examines the relationship between climate change and inflation using balanced panel data from 26 countries between 1995 and 2021. The primary objective is to empirically check the influence of temperature change on inflation within a country. To achieve this aim, the study employs panel fixed effects models, mediated effects models, and panel threshold models. The main findings of this investigation are summarized as follows: Firstly, the analysis reveals a significant and positive relationship between temperature increase, resulting from climate change, and the inflation level in a country or region. Importantly, these empirical findings remain robust even after controlling for the replacement of core explanatory variables, adjustments in the research year interval, and the exclusion of hyperinflationary countries. Secondly, the study reveals a non-linear relationship between temperature change and inflation, depending on the income levels of countries. Specifically, the findings identify two threshold values, namely 5618.95 and 6524.5, for GDP per capita. Within these threshold ranges, temperature change demonstrates a positive effect on the inflation level, which is statistically significant. Thirdly, the study shows that temperature change, through its impact on energy demand, ultimately contributes to an increase in the inflation level. Fourthly, the research highlights the differential vulnerability to temperature change between low and middle-income countries and the low-temperature group. Specifically, the inflation level in low and middle-income countries is more sensitive to temperature change compared to the low-temperature group.

In light of the aforementioned findings, this paper puts forth the following recommendations: Firstly, it is crucial to integrate climate change considerations into the framework of monetary policy.

The significant impact of temperature changes resulting from climate change on a country's inflation level underscores the necessity for central banks to incorporate climate-related factors into their monetary policy frameworks. This integration is essential as it forms the foundation for central banks to effectively pursue their monetary policy objectives. Climate change, as an exogenous shock, presents challenges for central banks in utilizing their current macroeconomic forecasting models to identify the origins of inflationary pressures and formulate effective responses to address them. Therefore, central banks should consider climate change in their monetary policies. In this way, they can enhance their risk identification and assessment processes regarding climate change-related risks, and make timely adjustments based on the scale and duration of climate change impacts. In addition, countries worldwide should strengthen national cooperation to effectively address the challenges posed by climate change. The impact of climate change on inflation exhibits a non-linear pattern, demonstrating variations across countries with diverse income levels. As a result, governments should actively engage in international exchange, cooperation, and the establishment of climate governance standards. By actively participating in these global initiatives and contributing to standard-setting processes, countries can accumulate invaluable international experience in climate governance. This experience serves to enhance their resilience in effectively managing and mitigating the consequences of climate shocks. Thirdly, researchers should study the intersection of climate change and economic development. The response to climate change should strive to achieve a harmonious synergy between reducing greenhouse gas emissions and fostering economic development. Achieving the climate governance objectives requires macroeconomic development-related indicators to ensure a balanced and sustainable approach to development that encompasses both environmental and economic dimensions.

Author Contributions: Conceptualization, Cunpu Li; methodology, Cunpu Li; software, Xuetong Zhang; validation, Cunpu Li, Xuetong Zhang and Jing He; formal analysis, Xuetong Zhang; investigation, Xuetong Zhang; resources, Xuetong Zhang.; data curation, Cunpu Li.; writing—original draft preparation, Xuetong Zhang; writing—review and editing, Cunpu Li.; visualization, Jing He; supervision, Jing He; project administration, Jing He; All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Informed Consent Statement: Not applicable.

References

1. Rudebusch G D. Climate change and the Federal Reserve[J]. FRBSF Economic Letter, 2019, 9(March 2019).
2. Doyle L, Noy I. The short-run nationwide macroeconomic effects of the Canterbury earthquakes[J]. New Zealand Economic Papers, 2015, 49(2): 134-156.
3. Heinen A, Khadan J, Strobl E. The price impact of extreme weather in developing countries[J]. The Economic Journal, 2019, 129(619): 1327-1342.
4. Batten S, Sowerbutts R, Tanaka M. Climate change: Macroeconomic impact and implications for monetary policy[J]. Ecological, societal, and technological risks and the financial sector, 2020: 13-38.
5. Faccia D, Parker M, Stracca L. Too hot for stable prices? International evidence on climate change and inflation[R]. mimeo, European Central Bank, 2020.
6. Klomp J, Sseruyange J. Earthquakes and economic outcomes: Does central bank independence matter?[J]. Open Economies Review, 2021, 32(2): 335-359.
7. Mukherjee K, Ouattara B. Climate and monetary policy: do temperature shocks lead to inflationary pressures?[J]. Climatic change, 2021, 167(3): 1-21.
8. Bansal R, Ochoa M. Temperature, aggregate risk, and expected returns[R]. National Bureau of Economic Research, 2011.
9. Dell M, Jones B F, Olken B A. Temperature shocks and economic growth: Evidence from the last half century[J]. American Economic Journal: Macroeconomics, 2012, 4(3): 66-95.
10. Liu M H, Li J L, Meng G F, Yang X W. How Does Temperature Shocks Affect Household Energy Consumption? In sights from Demand Heterogeneity [J]. Journal of Xi'an Jiaotong University (Social Sciences), 2022,42(04):74-85.
11. Zhu S, Lu X Y, Yang J, Cui J, She Y, Chen Y B, Wang W. Study on the Physical Risk of the Impact of Climate Change on Economic and Financial Systems[J]. Journal of Contemporary Financial Research,2022,5(01):63-76.
12. Li W T, Duan H B. Economic Impacts of Global Warming on China: Regional and Industrial Perspectives[J]. Journal of China University of Geosciences (Social Sciences Edition), 2022,22(04):128-141.

13. Liu B, Li Y Q, Jiang Y J. Climate Changes and the Total Factor Productivity of Manufacturing Enterprises :Mechanistic Analysis and Empirical Tests[J]. Journal of Hunan University (Social Sciences), 2023,37(01):78-87. 1.
14. Yang Q C, Luo L W. Impact of climate change on green technology innovation--Evidence from 81 developing countries[J]. China Soft Science, 2023(01):156-170.
15. Parker M. The impact of disasters on inflation[J]. Economics of Disasters and Climate Change, 2018, 2(1): 21-48.
16. Kunawotor M E, Bokpin G A, Asuming P O, et al. The impacts of extreme weather events on inflation and the implications for monetary policy in Africa[J]. Progress in Development Studies, 2022, 22(2): 130-148.
17. Odongo M T, Misati R N, Kamau A W, et al. Climate Change and Inflation in Eastern and Southern Africa[J]. Sustainability, 2022, 14(22): 14764.
18. Hsiang S M, Jina A S. The causal effect of environmental catastrophe on long-run economic growth: Evidence from 6,700 cyclones[R]. National Bureau of Economic Research, 2014.
19. Nordhaus W. Projections and uncertainties about climate change in an era of minimal climate policies[J]. American economic journal: economic policy, 2018, 10(3): 333-60.
20. Luo L W, Ru X, Zhao F. Advances in research on the economic impacts of climate change[J]. Economic Perspectives, 2018(10):116-130.
21. Debelle G. Climate change and the economy[C]//Speech at public forum hosted by Centre for Policy Development, Sydney, Australia, March. 2019, 12.
22. Yang L, Shi J Y, Chen X G. The Effect of Temperature Changes on China's Industrial Production and Mechanism Analysis[J]. J. China Econ. Q, 2020, 20: 299-320.
23. Yang X X. Climate Change, Environmental Governance and Economic Growth Based on Empirical Analysis of China[J]. Financial Development Review, 2022(06):23-37.
24. Feitelson E, Tubi A. A main driver or an intermediate variable? Climate change, water and security in the Middle East[J]. Global environmental change, 2017, 44: 39-48.
25. Pugatch T. Tropical storms and mortality under climate change[J]. World Development, 2019, 117: 172-182.
26. Lei X, Zhou J N. Climate Change and Macroeconomic Fluctuations in China: Analysis Based on DSGE Mode[J]. Study and Practice, 2022,(02),54-63.
27. Cavallo E, Galiani S, Noy I, et al. Catastrophic natural disasters and economic growth[J]. Review of Economics and Statistics, 2013, 95(5): 1549-1561.
28. Abe N, Moriguchi C, Inakura N. The effects of natural disasters on prices and purchasing behaviors: the case of the great East Japan earthquake [M]. Institute of Economic Research, Hitotsubashi University, 2014.
29. Simola H. Climate change and the Russian economy[J]. 2020.
30. Zhu Congmou, Li Wuyan, Du Yingying, et al. Spatial-temporal change, trade-off and synergy relationships of cropland multifunctional value in Zhejiang Province, China[J]. Transactions of the Chinese Society of Agricultural Engineering (Transactions of the CSAE), 2020, 36(14): 263-272.
31. Hou M Y, Yao S B. Spatial spillover effects and threshold characteristics of rural labor transfer on agricultural eco-efficiency in China[J]. Resources Science, 2018, 40(12):2475-2486.]
32. Hansen B E. Threshold effects in non-dynamic panels: Estimation, testing, and inference [J]. Journal of Econometrics, 1999, 93: 345 - 368
33. Wen Z L, Ye B J. Analyses of Mediating Effects: The Development of Methods and Models [J]. Advances in Psychological Science, 2014,22(05):731-74.
34. Wei R Q, Zheng L K. The Impact of Global Value Chain Division on Inflation and Its Mechanism Analysis[J]. Inquiry into Economic Issues,2022(06):134-148.
35. Yuan Y R, Cheng J H, Xu D Y, Cui X H. New Test of the Impact of Exports on the Green Production Efficiency of Enterprises[J]. Journal of China University of Geosciences(Social Sciences Edition),2020,20(01):68-82.
36. She Q Z, Wu X L, Pan A. Effects of climate finance on carbon emissions in recipient countries[J]. Resources Science, 2020, 42(6): 1015-1026.
37. Schultz K A, Mankin J S. Is temperature exogenous? The impact of civil conflict on the instrumental climate record in Sub-Saharan Africa[J]. . American Journal of Political Science, 2019, 63(4): 723-739.
38. Acaroğlu, H., & Güllü, M. (2022). Climate change caused by renewable and non-renewable energy consumption and economic growth: a time series ARDL analysis for Turkey. Renewable Energy. 193, 434-447.
39. Ahmad, T., & Zhang, D. (2020). A critical review of comparative global historical energy consumption and future demand: The story told so far. Energy Reports, 6, 1973-1991.
40. Yohannes H. A review on relationship between climate change and agriculture[J]. Journal of Earth Science & Climatic Change, 2016, 7(2).
41. Sperry J S, Venturas M D, Todd H N, et al. The impact of rising CO2 and acclimation on the response of US forests to global warming[J]. Proceedings of the National Academy of Sciences, 2019, 116(51): 25734-25744.

doi:10.20944/preprints202308.0059.v1

42. Kling G, Volz U, Murinde V, et al. The impact of climate vulnerability on firms' cost of capital and access to finance[J]. World Development, 2021, 137: 105131.
43. Enete A A, Amusa T A. Challenges of agricultural adaptation to climate change in Nigeria: a synthesis from the literature[J]. The Journal of Field Actions, 2010, 4.
44. Janjua P Z, Samad G, Khan N U, et al. Impact of climate change on wheat production: A case study of Pakistan [with comments][J]. The Pakistan Development Review, 2010: 799-822.
45. Gornall J, Betts R, Burke E, et al. Implications of climate change for agricultural productivity in the early twenty-first century[J]. Philosophical Transactions of the Royal Society B: Biological Sciences, 2010, 365(1554): 2973-2989.
46. Kirby J M, Mainuddin M, Mpelasoka F, et al. The impact of climate change on regional water balances in Bangladesh[J]. Climatic change, 2016, 135(3): 481-491.
47. Chen Y L. Issues in Current Central Bank Researches [J]. Journal of Financial Research, 2020(02):1-14.