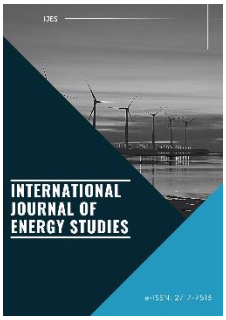
INTERNATIONAL JOURNAL OF ENERGY STUDIES

e-ISSN: 2717-7513 (ONLINE); homepage: https://dergipark.org.tr/en/pub/ijes



Research Article

Int J Energy Studies 2024; 9(1): 43-67

DOI: 10.58559/ijes.1409068

Received : 24 Dec 2023

Revised : 02 Feb 2024

Accepted : 13 Feb 2024

Mind the gap between the economic effect of climate change and the reality

Çağla Oduncular[a], Fatma Dahın[b], Eylül Kabakçı Günay[c], Meltem Ince Yenilmez[d*]

[a]Izmir Democracy University, Faculty of Economics and Administrative Sciences, Department of Economics, ORCID: 0000-0002-6827-97280000-0003-2964-8479

[b]Izmir Democracy University, Faculty of Economics and Administrative Sciences, Department of Economics, ORCID: 0000-0002-6827-97280000-0002-8890-1836

[c]Izmir Democracy University, Faculty of Economics and Administrative Sciences, Department of Economics, ORCID: 0000-0002-6827-97280000-0001-5547-4316

[d]Izmir Democracy University, Faculty of Economics and Administrative Sciences, Department of Economics, ORCID: 0000-0002-6827-97280000-0002-4689-3196

*(*Corresponding Author: meltеminceyenilmez@gmail.com)*

Highlights

- The economic impact of climate change is evaluated using panel data methodology.
- The impact of climate change on the economic growth of E7 countries between 2004 and 2021 was examined.
- Solutions that will be effective in combating climate change are discussed.
- According to the consequences of the analysis, it was concluded that climate change negatively affected economic growth.

You can cite this article as: Oduncular Ç, Dahın F, Günay EK, Yenilmez MI. Mind the gap between the economic effect of climate change and the reality. Int J Energy Studies 2024; 9(1): 43-67.

ABSTRACT

Climate change increases its severity day by day and poses a great threat to our world. Climate change problems almost cause the global economic system to be questioned. This issue is also very important for China, India, Brazil, Russia, Indonesia, Mexico and Turkey, which are expressed as E7 (developing) countries. Climate change forecasts for many countries predict that temperatures will rise as precipitation increases or decreases. Technological improvements are predicted to play an important role in mitigating and adapting to the negative consequences of climate change. This study aims to determine the effect of climate change on the economic growth of E7 countries between the years 2004-2021 using panel data methods. Analysis was done with the Stata 15 program. In the study, firstly, the literature on climate change and economic growth is included. Afterwards, the economic consequences of climate change are discussed. In the following section, solutions that will be effective in combating climate change are explained. Then, the empirical analysis and the obtained findings were included and the study was concluded with the conclusion and evaluation. All variables are statistically significant. Accordingly, while temperature and precipitation negatively affect GDP; Urbanization, population growth and HDI positively affect GDP. According to the consequences of the analysis, it was concluded that climate change negatively affected economic growth.

Keywords: Economic growth, Climate change, E7, Panel data methods.

1. INTRODUCTION

Climate change is a process that can be expressed as changes in the average temperature and precipitation values of the climate and climate characteristics and continues for many years. Climate Change has become one of the most terrible problems that the whole world has to deal with, especially in the 21st century. The impacts of climate change, which are on the agenda all over the world, appear as droughts experienced one after another or irregularities in the precipitation regime that cause excessive precipitation and floods. Climate change negatively affects many sectors, from agriculture to tourism and the energy sector. Especially the agricultural sector, which is a climate-based sector, is more affected by these climate changes. It poses a threat to countries whose economy is based on agriculture [1].

Global measures are taken to combat climate change, which has become a global problem. In this context, various agreements have been signed. The UN Framework Convention on Climate Change (UNFCCC), the world's first climate agreement to combat climate change, was signed on May 9, 1992 in New York. This convention, which was realized with the participation of 172 countries and opened for signature, was ratified by 189 countries, including the USA and Australia, two years later and entered into force on March 21, 1994 [2]. Another agreement on climate change is the Kyoto Protocol. This protocol was signed in 1997 in order to make the unfulfilled commitments with the UNFCCC binding on international law. It took place in Kyoto, Japan, with the participation of 154 states, under the leadership of the UN (United Nations), against the threats posed by climate change [3]. This protocol, which is a continuation of the UNFCCC agreement, was the beginning of concrete steps towards climate change [2]. Until the end of 2015, the two most important legal regulations on combating climate change were UNFCCC and Kyoto Protocol. However, UNFCCC was accepted at the 21st Conference of the Parties in 2015 and the Paris Agreement was signed and entered into force in 2016. This agreement has been signed by 195 countries and the EU (European Union) and has a critical role in shaping climate policies [4]. With the entry into force of the UNFCCC, which was created in the context of combating climate change, the Conference of the Parties, also known as COP, began to be held, in which the contracting parties actively participate. Negotiations on the applicability of the agreement were last held in 2023 under the name COP 28 and are hosted by different countries every year. In the Sustainable Development Program (UNDP), held in 2015, 17 sustainable development goals were adopted [5]. With the Climate Action target, the 13th of these universal targets, it is aimed to take

urgent measures to deal with climate change and its results. For this reason, it is of great importance to combat and adapt to climate-related hazards in all countries and to develop strategies about this.

It is inevitable that especially developing countries will be influenced by the economic effects of climate change more than developed economies [6]. The main variables that determine how societies are affected by climate change; economic development levels, population densities, income levels and distributions, local environmental conditions, ownership of food resources, quality of health services and ease of access to these services [7]. In this context, it would not be wrong to state that economies with insufficient infrastructure and low income will be more affected by global climate change. In the context, it is very significant to use new technologies and approaches to administrate risk in a changing climate. Green innovations, low-carbon or non-carbon economy and green technology concepts come to the fore, and the importance of climate investments is gradually increasing.

The pollution caused by economic growth and the sustainability of its pressure on the environment have necessitated the countries to use technologies that produce cleaner. For this reason, developed economies have started to switch to environmentally friendly production techniques, especially with the 1990s. However, developing countries have continued to increase their production despite the negative effects on the environment due to high costs [8]. Especially in developing countries where energy consumption rates are high and environmental management is not fully associated with infrastructure, environmental problems have begun to be felt more clearly [9].

The most important factor causing climate change is the damage done to the environment in line with economic interests. In this process, developed countries maintain their current positions; developing economies, on the other hand, have entered the race to produce and consume at the expense of environmental pollution in order to progress towards becoming a developed country. Developing countries whose main objective is development; they are hesitant to endanger this goal by implementing environmental policies and to smuggle foreign capital. This situation causes dirty industries to shift from developed countries to developing countries [10].

2. LITERATURE REVIEW

Climate change is a very important issue for developed and developing economies. It is considered a threat to the sustainability of the global economy as it is closely related to the performance of

various macroeconomic indicators. In this regard, in recent years, studies by scientific and political circles to reveal the current and possible effects of climate change have been increasing. In the last quarter century, there has been a rapid increase in the number of studies examining the relationship between climate change and the economy both empirically and theoretically [11, 12].

According to Başoğlu's [13] study in which he investigated the economic impacts of climate change, climate change has important repercussions on sectors such as agriculture, tourism and energy, as well as on labor productivity, employment and growth. Especially as a result of extreme fluctuations in temperature rise and precipitation patterns, climate change has significant impacts on economies. Accordingly, although it has some positive effects in some countries, it is seen that the global net effect of climate change is negative.

Studies examining the relationship between climate change and economy concentrates on agriculture [14, 15, 16, 17, 18, 19], tourism [20, 21, 22, 23, 24], employment [25, 26] and economic growth [1, 27, 28, 29, 30, 31]. In the literature on the economic effects of climate change, especially the relationship between climate change and economic growth is one of the increasingly popular topics.

Climate change and its economic effects have been studied by many researchers, and the results differ for the method used, time zone and country group. When the relevant literature is examined, the variables of temperature, precipitation amount and CO_2 emission are used intensively in studies on climate change.

Many researchs in the literature have examined the effect of climate variables on economic growth. Dell et al. [32] for (125 countries) Sub-Saharan Africa and out of Sub-Saharan Africa, Bernauer et al. [33] for African countries, and Akram and Gulzar [29] for Pakistan, Belford et al. [34] for Gambia found that climate change leads to an decrease in economic growth. Contrary to the findings of these studies, Knight and Schor [28] for 29 high-income countries, and Kara and Diken [35] for Turkey found that climate change leads to an increase in economic growth. However, there are researches in the literature that found significant results with different indicators of climate change, as well as studies that could not find any relationship between some variables [36]. In the literature consisting of these studies, there is no consensus on whether climate change variables cause an rise or fall in economic growth.

Alagidede et al. [27] examined the effect of climate change on sustainable economic growth in Sub-Saharan African countries. Precipitation and temperature variables as indicators of climate change in the research; GDP per capita was used as an variable of economic growth. Panel cointegration technique was applied in this study which covers the period 1970-2009. Accordingly, the long-term and short-term effects of temperature and precipitation on economic growth are different. In the short run, temperature increases reduce economic growth. In addition, long-term adaptation to climatic conditions can be achieved. Akram and Gulzar [29] analyzed the effect of climate change in Pakistan on economic growth for the 1973-2010 period using the time series method. Within the scope of the analysis; GDP, investment, labor, opennes, agriculture, manufacturing, services, expenditure and temperature variables are used. As a result, it was seen that the temperature negatively affected the GDP, agriculture, manufacturing and service sectors. Compared to other sectors, this negative effect is more in the agricultural sector. Nawaz et al. [31] analyzed the effect of climate change on economic growth with the random effect model (REM) and system GMM. The study conducted for 91 countries for the year 1999-2014 shows that climate change and corporate governance have a positive effect on economic growth, while the square of CO_2 emissions has a negative effect on economic growth. The square term is negative and supports the nonlinear relationship between CO_2 emissions and economic growth. It shows that emissions initially stimulate economic growth, but after a point, emissions cause a decline in economic growth, causing climate change that is dangerous to health, agriculture and all living organisms on earth. Knight and Schor [28] researched the relationship between economic growth and greenhouse gas emissions for 29 high-income country groups using the balanced panel method, based on the period 1991-2008. For analysis; territorial emissions, consumption-based emissions, GDP per capita, export %GDP, import %GDP, urban % population variables are used. Despite the increase in greenhouse gas emissions and economic growth, It is essential to take measures to decrease the possible negative results of climate change.

It is seen that studies on climate change and its economic effects vary considerably. When the relevant literature is examined, frequently in studies; temperature, precipitation and CO_2 emissions are used as indicators of climate change, and Gross Domestic Product (GDP) per capita data is used as an indicator of economic growth. Accordingly, studies examining climate change and its economic effects have yielded different results for different variables, different time periods and different country groups.

3. THE ECONOMIC RESULTS OF CLIMATE CHANGE

Climate change refers to changes in the climate that occur in the natural process or as a result of human activities [37]. Climate change affects the whole world, and the costs and benefits of this climate change vary from country to country [27]. Climate change increases CO_2 and as a result of this increase, temperatures rise and precipitation regimes deteriorate. These developments as a result of climate change may cause advantages for some regions and disadvantages for others. In general, although temperature increases reduce product productivity and quality, they can create positive effects for some regions. Increases in precipitation, on the other hand, increase soil moisture in many regions and benefit arid and semi-arid areas, and in some cases may cause negative results [37]. The economic results of climate change are seen in many sectors, especially in agriculture, tourism and energy.

The most affected sector is the agricultural sector. Because temperature and precipitation are assumed to be direct inputs in the agricultural sector. When studies on climate change are examined, it has been observed that there are negative effects for many countries. However Considering the studies conducted in the USA, it has been observed that the negative impacts of climate change on agriculture are lower. U.S. farmers take the most appropriate decisions in their agricultural practices in order to reduce the potential productivity declines that may arise due to climate changes. However, studies for developing economies have serious negative effects on the agricultural sector due to insufficient precipitation and high temperatures in these countries. Although the agriculture sector of India and Brazil is not resistant to climate change, farmers are aware of this and take precautions against climate change. It has been observed that the measures taken against climate change in developing countries are insufficient. Especially in some regions, climate changes can cause various diseases. An example of this is the spread of malaria in India [29]. The agricultural sector, which has an important place in the Turkish economy, is seriously affected by climate change and is a sector that is likely to be affected during the period when the necessary measures are not taken. Increases in the amount and quality of agricultural production that may occur due to climate change will negatively affect the economy of the country as well as the economy of the people who make their living from agriculture [13]. Another sector that is influenced by global climate change and is likely to be affected in the future is the tourism sector. Excessive increase in temperatures will cause droughts and cause many touristic areas to lose their attractiveness. At the same time, the increase in temperature will cause the glaciers to melt and the rising waters may damage many touristic coastal areas. Overheating not only affects summer

tourism, but also affects winter and ski tourism if sufficient snow is not reached [38]. Another sector affected by climate change is the energy sector. Due to climate change, temperatures increase and precipitation regimes deteriorate. Depending on these changes, while water levels decrease in some regions, flood disasters occur in some regions. As a result of all these, energy supply and demand are greatly affected [39].

Increasing CO_2 as a result of climate change constitutes a large part of the greenhouse gas emissions of countries. In general, emission levels increase with the increase in the need for infrastructure services together with the increasing population in developed and developing countries. As of 2021, the first 15 countries with the highest CO_2 emissions in the world and the status of the E7 countries among these countries are shown in figure 1 [40].

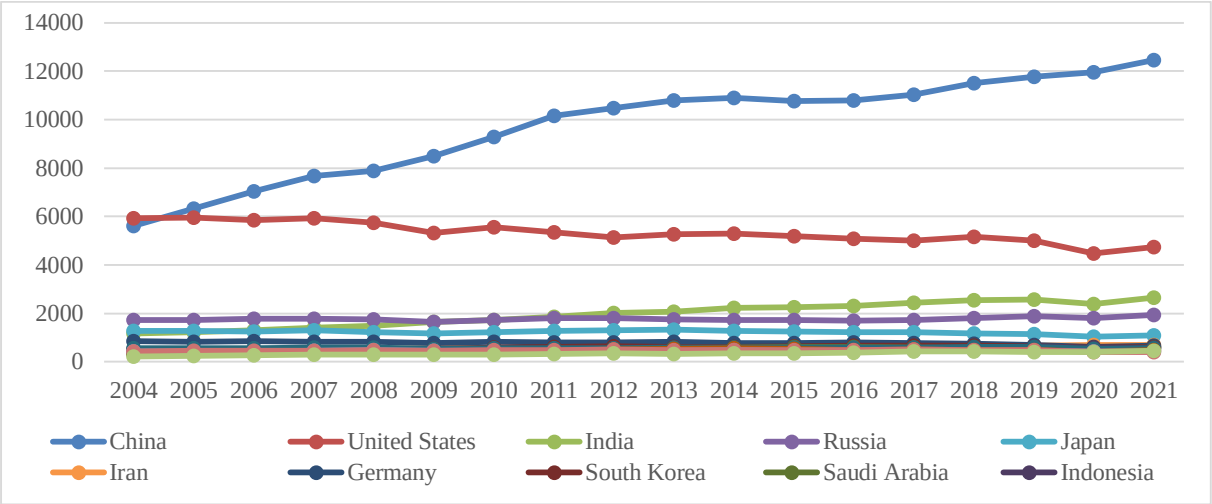


Figure 1. CO_2 emissions totals by country (Million tons CO_2)

When figure 1 is examined, it is seen that the countries with the highest CO_2 emissions worldwide are China and America. As can be seen in the figure, the highest CO_2 emission is realized by China as 12,466,315 million tons as of 2021. After China, the second country with the highest CO_2 emissions worldwide is the USA with 4,752,079 million tons. In 2021, CO_2 emissions of E7 countries other than China were realized as India 2,648,779 million dollars, Russia 1,942,535 million dollars, Indonesia 602,593 million dollars, Brazil 489,857 million dollars, Mexico 418,347 million dollars, Turkey 449,724 million dollars. As can be seen in the graphic; to summarize, in the 21st century, CO_2 emissions have increased continuously for all countries every year. Although

there was a decrease in 2020 with the effect of the COVID-19 pandemic, which started to spread in 2019, it started to increase again the next year.

4. THE ECONOMIC RESPONSE TO CLIMATE CHANGE

Climate change is a global, serious and urgent problem in terms of its causes and consequences. Climate risk, which has many possible consequences that are intertwined economically, socially and environmentally, will directly or indirectly affect everyone. In this context, while the global economic system aims to achieve sustainable development, it has to struggle with the reality of climate change, the effect of which is irreversible today. It is a fact that the fight against climate change cannot be evaluated only on a plane between the atmosphere and pollutants, but this fight is closely related to economic policies.

In the process from past to present, countries have sought many solutions within the scope of combating climate change, held conferences on this issue and signed various agreements. However, in order to stop the global climate crisis, which is a result of the obsession with industrialization and economic growth, and to reduce its effects, both the warnings and suggestions made by international organizations and international agreements may be ineffective [41]. This situation necessitated a more comprehensive approach. In this context, concepts such as investment in green innovation, carbon efficiency and technology come to the fore in the fight against climate change. In order to prevent climate change and succeed a sustainable future, the worldwide trend towards a low-carbon economy should be supported and plans should be made urgently in this direction [42]. In this process, investment in comprehensive green innovations and technological solutions are very important.

Green innovation is sustainable innovation that includes new or modified processes and technologies that are environmentally friendly and environmentally friendly (eco-innovative). However, in green innovation, rational, efficient and sustainable use of natural resources; environmental awareness is created by offering new green products and services (prevention of pollution, recycling, energy efficiency and energy saving) to consumers [43]. Green innovation defines as product and process innovation that includes the improvement of new technologies, but focuses on eco-efficient designs, pollution prevention, waste recycling and energy saving [44]. In addition to this definition, green product and hardware or software innovations related to these processes or corporate environmental management are also expressed as green innovation [45]. It

demonstrates green innovation, improving energy systems and architecture, and teaching alternative production and consumption systems that are more environmentally friendly than existing systems. In this context, pollution control and cleaning technologies, new manufacturing processes that compose less pollution or use more resources, and green energy technologies and new or environmentally improved products are included in the scope of the green innovation system [46]. That is, green innovation is not only about processes, but also about products produced by the company, packaging and energy use. Green innovations result in less waste and less product costs, while reducing dependency on chemicals and increasing eco-efficiency. Green innovation management is an effective management model in combating climate change by decreasing greenhouse gas emissions by using smart technology and systems, rising the use of renewable energy sources, and reducing waste products.

Climate change is a long-term consequence of carbon-based economic growth. Climate scientists expect carbon intensity to double over the next century, impacting average temperatures by about 1 degree Celsius by 2050 and by 2.5 degrees Celsius by 2100 [47]. In this context, an urgent worldwide action plan towards a climate-friendly, low-carbon economy is required to reverse the trend towards higher global temperatures. One of the new concepts emerging in the coping with climate change is decarbonization of life and economy and reducing the dependence of economic activities on carbon. The most accepted definition of this concept is “low carbon economy” [48]. Low carbon economy is a model that aims to provide the energy required for all economic activities occurring in the manufacturing and consumption chain in an economy by producing the lowest or zero level of carbon emissions. In this direction, spreading the preference of especially energy saving and renewable energy sources, improvement technologies, ensuring the orientation towards low-carbon-intensive energy sources, making environmentally harmless and low-carbon technologies widespread constitute the cornerstones of the low-carbon economy, which is a world economy. sustainable and pro-innovation approach [49]. Emissions trading, carbon tax and carbon credits government regulations and taxation measures are designed as regulatory measures that encourage countries to reduce their carbon emissions [50]. It is expected that carbon capture, use and storage practices will play an significant role in the fight against high carbon emissions in the coming periods [51].

Industrialized countries are seen as responsible for just over two-thirds of the carbon dioxide that accumulates in the atmosphere. The two major economies in the world, the USA and China,

together account for 40% of global carbon emissions. China ranks first in global greenhouse gas emissions with 26.8%, followed by the USA with 13.1%, the European Union with 9% and India with 7% [52]. While these countries cause the highest greenhouse gas emissions worldwide, the European Union, India, Japan and China are the regions and countries that have the resources and technologies to produce clean energy. China is the largest sovereign investor in renewable energy and low-carbon resources to prevent pollution and support the transition to green energy [53]. However, China, along with Japan and Australia, are making investments to store the power they produce with renewable energy. Thus, while increasing energy security, the decrease in energy imports means an advantage in foreign trade [54]. Determination of reduction targets for developed and developing countries is progressing rapidly under the headings of adaptation to the results of climate change, technology and financing. The economic costs to stabilize greenhouse gas emissions depend on the development of new technologies in the energy sector [52]. Green technology aiming to develop environmentally friendly products and services; It is a technology that helps prevent negative climate effects in the future and use resources efficiently. In this context, decrease of greenhouse gas emissions, efficient information, use of renewable energy sources, reduction of waste materials and smart innovative technological applications are the solutions that can be effective in the coping with climate change [55]. Table 1 [56] shows the Green Future Index values and the ranking of countries.

Table 1. The green future index country rankings, 2021-2022

Country	**Rank (2022)**	**Rank (2021)**	**Score (2022)**
Iceland	1	1	6.92
Denmark	2	2	6.55
Netherlands	3	10	6.42
United Kingdom	4	17	6.29
Norway	5	3	6.21
China	26	45	5.27
Brazil	34	32	4.96
India	42	21	4.73
Mexico	54	36	4.23
Russia	64	73	3.89
Turkey	69	68	3.71
Indonesia	70	57	3.68
Guatemala	72	70	3.49

Qatar	73	76	3.35
Paraguay	74	75	3.34
Algeria	75	72	3.16
Iran	76	74	2.67

The green future index has been published since 2021 and shows the ranking of their progress and announced commitments in building a sustainable, low-carbon future for the economies of 76 countries and regions. In addition, this index measures the extent to which national economies return to the energy, industry and agriculture sectors and society through investments in innovation, renewable energy and the environment. The index consists of 5 different categories: Carbon emissions, Energy transition, Green society, Clean innovation, and Climate policy. The climate policy category accounts for the largest share in the Green Future Index, with 40% of the overall rankings. This category consists of many indicators such as countries' climate policies, carbon management strategies and green project investments. When we look at the values in Table 1, Iceland, Denmark and Netherlands are in the top 3; We see that Paraguay, Algeria and Iran are in the last 3 places. Among the E7 countries, China ranks 26th, Brazil 34th, India 42nd, Mexico 54th, Russia 64th, Turkey 69th and Indonesia 70th.

5. DATA AND METHODOLOGY

In the research, the economic effect of climate change was examined in the E7 countries (China, India, Brazil, Mexico, Indonesia, Russia and Turkey), which are known as the countries with a high development rate. In this direction, Panel Data Regression method was used for the years 2004-2021 as the analysis method. In this direction, data for E7 countries were used and related data were obtained from the World Bank (WB), United Nations Food and Agriculture Organization (FAOSTAT) and UNDP Human Development Report. In this study, economic growth as a dependent variable, changes in temperature and precipitation as an independent variable; The share of urban population in total population, total population and human development index were used as explanatory variables. Logarithmic forms of Gross domestic product, precipitation and population indicators were used in the analysis.

The model created in the study to examined the effect of climate change on economic growth is shown in equation 1.

$$Ingdp_{it} = \beta_0 + \beta_1 temp_{it} + \beta_2 Inpreci_{it} + \beta_3 urbanpop_{it} + \beta_4 Inpop_{it} + \beta_5 hdi_{it} + \varepsilon_{it} \quad (1)$$

The empirical analysis was started by looking at the summary statistics of the variables used first. Stata 15 econometric package program was used to create the table of these statistics. Table 2 shows the information of indicators used in the model.

Table 2. Information about variables [57, 58, 59, 60]

Abbreviations	Variable Name	Explanation	Source
Ingdp (dependent variable)	Gross domestic product	GDP in 2017 fixed prices by purchasing power parity	World Bank (WB)
Temp	Temperature	Changes in temperature	Food and Agriculture Organization of the United Nations (FAOSTAT)
Lnpreci	Precipitation	Annual precipitation	World Bank Climate Change Knowledge Portal
urbanpop	Urban population	Urban population (% of total population)	World Bank (WB)
Inpop	Population	Total population	World Bank (WB)
Hdi	Human development index	Human development index	UNDP, Human Development Reports 2022

The pooled least squares method was preferred to determine whether the variables in the model were significant and to test the entire model. Then, the unit effect or unit and time effect of the model was tested. Fixed effects and Random effects models are used as economic methods. Hausman specification test was used to prefer which of the fixed and random effects model estimators would be used. Fixed Effects Models are models in which the slope coefficients are the same for time and cross-section units, and the constant coefficient varies between cross-section units. The fixed effects model is grouped as one-way and two-way models. If there is a difference between the sections in the panel variables but there is no time-dependent difference, then the regression model to be created will be a one-way and section-dependent fixed effects model. However, if there is only a time-dependent variation, it is named a time-dependent fixed effects

model. The model in which the changes in the cross-section and time series data are taken into account is the bidirectional fixed effects model [61]. In the random effects model, partitions or changes due to partitions and time are added to the model as a part of the error term. In this case, there is no loss of degrees of freedom encountered in fixed effect models. In the random effects model, besides the consequences of the cross-sections and differences in the sample observed over time, effects outside the sample are also taken into account [62]. According to the Hausman specification test, the random effects model was decided as the appropriate method and other tests were performed for empirical analysis.

While estimating the panel data, some assumptions are made such that there is no heteroscedasticity, autocorrelation and cross-sectional dependence. After deciding on the appropriate model as a consequence of the Hausman test, deviations from this assumption were tested with appropriate tests. Subsequently, the model was estimated with robust standard errors and coefficient interpretations were obtained.

6. ANALYSIS OF RESULTS

In this part of the study, the consequences of the analysis are included. All the results obtained are summarized in the tables. In the study, first an econometric model was established, then the summary statistics of the indicators were examined and are seen in the table 3.

Table 3. Summary statistics on variables

Variable	Observation	Average	Standard deviation	Minimum	Maximum
Ingdp (dependent variable)	126	28.8999	.7136352	27.7595	30.84434
Temp	126	1.122786	.566913	.223	3.691
Lnpreci	126	6.874372	.6062974	6.123983	8.098451
Urbanpop	126	63.60654	17.85568	28.903	87.317
Inpop	126	19.42152	1.063306	18.03185	21.06853
Hdi	126	.7221587	.0743814	.525	.845

Table 4 shows the Likeliness Ratio (LR) test results. With the LR test, the model's unit effect and time effect were tested. Thus, it has been determined whether the model is a one-way model

containing the unit or time effect, or a two-way model containing both the unit effect and the time effect [63]. Accordingly, the H_0 hypothesis was established as "there is no unit and time effect" or "there is only unit effect and only time effect". H_0 hypothesis is valid for the classical model. According to the results obtained in the study, the H_0 hypothesis was rejected. Afterwards, the unit effect was tested with the LR test and the result was significant. Subsequently, this time the time effect was tested and the existence of the time effect was rejected. Accordingly, the model is a one-way unit effect model.

Table 4. LR test results to test for the presence of unit and time effects

Group variable	LR statistics	P value	Test result
Unit and time	47.84	0.0000	Has a unit or time impact
Unit	47.84	0.0000	Has a unit effect
Time	1.8	1.0000	Has no time effect

According to the tests applied, the unit or time effects was tested. However, it should be considered whether these effects are fixed or random. In this context, Hausman test was used to choose between estimators in panel data models.

Table 5 shows the consequences of the random effects model, while table 6 shows the Hausman test result.

Table 5. Model estimated by random effects method

Variable	Coefficient	Standard Error	z statistics	P>|z|
Temp	-.0480845	.0192501	-2.50	0.012
Lnpreci	-.104645	.015986	-6.55	0.000
Urbanpop	.0033292	.0009469	3.52	0.000
Lnpopt	.8752851	.0121347	72.13	0.000
Hdi	5.706079	.255742	22.31	0.000
Constant	8.341444	.3707993	22.50	0.000
R^2 = **0.9854**				
Wald chi2(5) = 8103.08 **Prob>chi2 = 0.0000**				

According to the random effects model in Table 5, the R^2 value testing the explanatory power was high and the probability value of the independent variables was 0.05 small, giving significant results. Accordingly, the independent variables used in the model explain approximately 98% of the changes in GDP, which is the dependent variable. While temperature and precipitation indicators, which are used as indicators of climate change, affect GDP negatively, urbanization, population growth and HDI have a positive effect on GDP. Hausman test was performed to decide which model is suitable and the results are presented in Table 6.

Table 6. Hausman test results

Test Statistics	Probability Value
chi2(5)	6.06
Prob>chi2	0.3005
H_0 = The difference between the coefficients is not systematic.	

According to the basic hypothesis that the Hausman test random effects estimator is valid, the H_0 hypothesis is "there are random effects", while the alternative hypothesis is "there are no random effects". In this situation, the null hypothesis is rejected because the probability value is smaller than 0.05. It means that the model is a fixed effect model. In the results of Table 6, the p value of the null hypothesis, which states that there are random effects in the Hausman test, is 0.3005 and is higher than 0.05. This means accepting the H_0 hypothesis. Accordingly, the random effects model was used while creating the regression model.

While estimating the panel data, some assumptions are made such that there is no varying variance, autocorrelation and cross-sectional dependence. After deciding on the appropriate model as a consequence of the Hausman test, deviations from this assumption were tested with appropriate tests. Subsequently, the model was estimated with robust standard errors and coefficient interpretations were obtained.

When estimating the panel data, it is necessary to analysis the heteroscedasticity (varying variance), autocorrelation and cross-section dependence. It is necessary to test them to show whether they exist or not, and if there are, to apply estimation methods that take care of these problems.

Table 7 shows the inter-unit correlation, heteroskedasticity and autocorrelation test results. Modified Wald Test was used to test that there is a heteroscedasticity problem. The test results showed that there is a problem of heteroskedasticity in the model. Durbin Watson test was implemented to test the existence of autocorrelation problem in the model. According to test results, it was determined that there was an autocorrelation problem in the model. Friedman's Test was conducted to investigate the cross-sectional dependence. According to the test cosequence, there is a cross-section dependency in the model.

Table 7. Testing of heteroscedasticity, autocorrelation and cross-sectional dependence

Deviations from the assumption	**Test Name**	**Test statistics**	**Result**
Heteroscedasticity	Modified Wald Test	W0=8.2758799 Pr>F= 0.00000017 W50=6.1146733 Pr>F= 0.00001308 W10=7.6958788 Pr>F= 0.00000053	Heteroscedasticity was
Autocorrelation	Durbin Watson Test	Durbin-Watson = .35173878 Baltagi-Wu LBI = .55498743	Autocorrelation was
Horizontal cut dependency	Friedman's Test	Pr = 0.0203	Horizontal cross-section has dependency

Even if a model has heteroskedasticity, autocorrelation and cross-section dependence according to units, it can make predictions that are resistant to these deviations. Table 7 shows that there is heteroskedasticity and autocorrelation in the model. In that case, the model was estimated with Driscoll-Kraay standard errors in a way that would be resistant to deviations from all assumptions [64].

Table 8 contains the consequences of the Driscoll-Kraay resistant standard errors model for the random effects model. The model is a one-way unit effect random effects model. Testing the explanatory power, the R^2 value is 98.5%, which is quite high. According to the estimation results of the new model, whose current specification problems have been resolved, it has been observed that the precipitation and temperature variables had a negative effect on the GDP. Urbanization, population growth and HDI explanatory variables have a positive effect.

Table 8. Results of the Driscoll-Kraay Resistant Standard Errors Model for the random effects model

Variables	Coefficient	Drisc/Kraay Std. Err.	T statistics	P>|t|
Temp	-.0480845	.0179923	-2.67	0.016
Lnpreci	-.104645	.0119795	-8.74	0.000
urbanpop	.0033292	.0009426	3.53	0.003
Lnpopt	.8752851	.022458	38.97	0.000
Hdi	5.706079	.3171385	17.99	0.000
Constant	8.341444	.6381615	13.07	0.000
Wald chi2(5) = 28366.97				
Prob > chi2				
overall R-squared = 0.9854				

All variables are statistically significant. Accordingly, while temperature and precipitation negatively affect GDP; urbanization, population growth and HDI affect GDP positively. In other words, climate change has reduced economic growth. The reason for this can be said to be irregular temperature and precipitation regimes [65]. The uneven distribution of temperature and precipitation creates adverse effects on economic activities by creating effects such as unusual drought and unusual precipitation. The results presented in the study showed that climate change negatively affects economic growth in E7 countries.

7. CONCLUSION

Although climate change is a natural concept that has continued throughout the history of the world, it has become a worldwide problem since the middle of the 19th century (Industrial Revolution), depending on human activities. It negatively affects agriculture, tourism, energy sector, employment, human capital and economic growth due to extreme temperatures and deterioration in precipitation regime. Some measures are taken to combat these problems felt all over the world due to climate change. Various agreements have been signed for this purpose. The first of these is the UNFCCC, which is accepted as the world's first climate agreement and signed in New York in 1992. Later, the weak sanction power of the UNFCCC revealed the need for the implementation of the legal regulation, which has binding and more concrete objectives. For this reason, the Kyoto Protocol was signed in 1997 and this agreement entered into force in 2005.

Afterwards, the Paris Agreement was signed for the period after 2020, which will replace the Kyoto Protocol. With this agreement, the reality of how serious a problem climate change is for the entire planet has been revealed.

Climate change, which has many economic, social and environmental impacts, requires a global response. Green innovations, carbon efficiency and technological development are important weapons in the fight against climate variability. Green innovation is the meeting of sustainable production with the aim of protecting nature and innovative ideas and innovative tools. By investing in low-carbon technologies and production processes, carbon costs can be reduced, thereby reducing emissions intensity and maintaining output. However, reducing greenhouse gas emissions, efficient information, utulize of renewable energy sources, diminishing waste materials and smart innovative technological applications are solutions that can be effective in combating climate change.

In this research, panel data analysis was conducted for E7 countries to examined the relationship between climate change and economic growth between 2004-2021. In this context, Fixed Effects and Random Effects models are used. The results were negative and significant with temperature and precipitation economic growth; urban population, total population and human development index show a positive and significant relationship on economic growth. It has been concluded that the temperature and precipitation variables used in the study as an indicator of climate change have a negative effect on the GDP, which is taken as an indicator of economic growth, as expected. And the results obtained show parallelism with the studies in the literature. Dell, Jones, and Olken [32], Akram and Gulzar [29], Alagidede, Adu and Frimpong [27], Jatuporn and Takeuchi [19], study finds that the negative effect of temperature on economic growth; Ali [66], Akram [67], Kotz, Levermann, and Wenz [68] study findings have similar results with this study, which shows that precipitation has a negative effect on economic growth. The negative impact of temperature and precipitation on the economic growth of E7 countries; This can be said as the fact that the related countries are in the category of developing countries and therefore the agricultural sector is predominantly economically dependent on the change in the climate. In addition, effects such as unusual drought and unusual precipitation that occur during the climate change process have negative effects on economic activities. Negative effects on economic activities are not only limited to the agricultural sector, but also hinder industrial growth [65].

Considering a problem such as climate change, which may pose serious dangers in the future, it becomes clear that future energy policies need to be reconsidered. Climate change reduces the economic growth rate, especially in developing countries. Although some measures have been taken to solve the problems arising from climate change at the international level through climate agreements, these are not sufficient. Since climate change does not have a border like country borders, it has been accepted globally that both local, regional, national and global action should be taken in order to combat it effectively, and that a harmony between science, society, media and countries should be achieved in order to achieve success in this fight. For this reason, measures should be taken at both national and international level and policies should be developed at the point of combating climate change. In this context, countries should reduce the amount of energy they consume as much as possible or they should be encouraged to use energy sources with low CO_2 emissions. In addition, the competent authorities should ensure that countries' infrastructure plans are designed in accordance with climate change, and strategies should be improved to decrease the dependence of economic activities on precipitation and temperatures. In order to realize all these plans and policies; Countries should also allocate financial resources in order to meet their financing needs in the dealing with climate change and take the necessary measures to minimize the climate change problem by making use of rapidly developing technological opportunities.

NOMENCLATURE

UNFCCC	The UN Framework Convention on Climate Change
UN	United Nations
EU	European Union
UNDP	United Nations Development Programme
CO_2	Carbon Dioxide
COP	Conference of the Parties
GDP	Gross Domestic Product
REM	Random Effect Model
GMM	Generalized Method of Moments
OECD	Organisation for Economic Co-operation and Development
WB	World Bank
FAOSTAT	United Nations Food and Agriculture Organization
HDI	Human Development Index

LR Likeliness Ratio

ACKNOWLEDGMENT

Analyzes and comments made in this document belong to the authors. Article is not supported by any institution, company, and etc.

DECLARATION OF ETHICAL STANDARDS

The authors of the paper submitted declare that nothing which is necessary for achieving the paper requires ethical committee and/or legal-special permissions.

CONTRIBUTION OF THE AUTHORS

Meltem İnce Yenilmez, Eylül Kabakçı Günay, Çağla Oduncular and **Fatma Dahın** have contributed equally to the study. All authors contributed equally to the data collection, analysis, writing of the article, and the overall concept and design of the study. All authors read and approved the final manuscript.

CONFLICT OF INTEREST

There is no conflict of interest in this study.

REFERENCES

[1] Odusola A, Abidoye B. Climate change and economic growth in africa: An econometric analysis. Journal of African Economies, 2015; 24(2): 1-25.

[2] Köse İ. İklim değişikliği müzakereleri: Türkiye'nin Paris Anlaşması'nı imza süreci. Ege Staratejik Araştırmalar Dergisi, 2018; 9(1): 55-81.

[3] Bodansky D. International Law and the Design of a Climate Change. U. Luterbacher, & D. F. Sprinz (in) International Relations and Global Climate Change. The MITI Press, London, 2001; 201-219.

[4] Keskin MH, Kökyay F. Paris Anlaşmasına giden süreçte AB İklim Değişikliği ve Çevre Politikaları. Kafkas Üniversitesi Sosyal Bilimler Enstitüsü Dergisi, 2020; 0(25): 289-314.

[5] UNDP. The Sustainable Development Goals Report 2022. United Nations, 2022. https://unstats.un.org/sdgs/report/2022/The-Sustainable-Development-Goals-Report-2022.pdf (14.04.2023)

[6] McGuinan C, Reynolds R, Wiedmer D. Poverty and climate change: Assessing impacts in developing countries and the initiatives of the international community, 2002.

[7] Kadıoğlu M. Türkiye'de iklim değişikliği risk yönetimi. Türkiye'nin İklim Değişikliği II. Ulusal Bildiriminin Hazırlanması Projesi Yayını, 2012.

[8] Artan S, Hayaloğlu P, Seyhan B. Türkiye'de çevre kirliliği, dışa Açıklık ve ekonomik büyüme ilişkisi. Journal of Management and Economics Research, 2015; 13(1): 308-325.

[9] Çetin M, Doğan İ, Işık H. Enerji tüketiminin çevre kirliliği üzerindeki etkisi: Bir panel veri analizi. International Anatolia Academic Online Journal Social Sciences Journal, 2014; 2(1): 15-29.

[10] Mutlu A. Küresel kamusal mallar bağlamında sağlık hizmetleri ve çevre kirlenmesi: Üretim, finansman ve yönetim sorunları. Maliye Dergisi, 2006; 150: 53-78.

[11] Auffhammer M. The (Economic) impact of climate change: Some implications for Asian economies. ADBI Working Paper, 2019; 1051: 1-27.

[12] Kahn ME, Mohaddes K, Ng R, Peseran M, Raissi M, Yang JC. Long-term macroeconomic effects of climate change: A cross-country analysis. IMF Working Paper19/215, 2019; 1-58.

[13] Başoğlu A, Telatar OM. İklim değişikliğinin etkileri: Tarım sektörü üzerine ekonometrik bir uygulama. KTÜ Sosyal Bilimler Dergisi, 2013; 6: 8-25.

[14] Akalın M. İklim değişikliğinin tarım üzerindeki etkileri: Bu etkileri gidermeye yönelik uyum ve azaltım stratejileri. Hitit Üniversitesi Sosyal Bilimler Enstitüsü Dergisi, 2014; 7(2): 351-378.

[15] Hayaloğlu P. İklim değişikliğinin tarım sektörü ve ekonomik büyüme üzerindeki etkileri. Gümüşhane Üniversitesi Sosyal Bilimler Enstitüsü Dergisi, 2018; 9(25): 51-62.

[16] Ladrera R, Cagasan U. A review on the impact of climate change on agriculture sector: Its implication to crop production and management. Eurasian Journal of Agricultural Research, 2022; 6(1): 52-61.

[17] Dumrul Y, Kılıçaslan Z. Economic impacts of climate change on agriculture: Empirical evidence from ARDL approach for Turkey. Journal of Business Economics and Finance, 2017; 6(4): 336-347.

[18] Xiang T, Malik T, Hou J, Ma J. The Impact of Climate Change on Agricultural Total Factor Productivity: A Cross-Country Panel Data Analysis, 1961-2013. Agriculture, 2022; 12: 1-20.

[19] Jatuporn C, Takeuchi K. Assesing the Impact of Climate Change on the Agricultural Economy in Thailand: An Empirical Study Using Panel Data Analysis. Environmental Science and Pollution Research, 2022; 30(3): 8123-8132.

[20] Hamilton JM, Tol R. The Impact of Climate Change on Tourism and Recreation. Working Papers FNU-52, Research Unit Sustainability and Global Change, 2004.

[21] Mishev P, Mochurova M. Climate Change Impacts on Tourism. International Conference Global Environmental Change: Challenges to Science and Society in Southeastern Europe. Sofia, Bulgaria, 2008.

[22] Ramasamy R, Swamy A. Global Warming, Climate Change and Tourism: A Review of Litarature. Cultur Revista de Cultura e Turismo, 2012; 6(3): 72-98.

[23] Agnew MD,Viner D. Potential Impacts of Climate Change on International Tourism. Tourism and Hospitality Research. 2001; 3(1): 37-60.

[24] Dereli M, Boyacıoğlu E, Terzioğlu M. İklim Değiişinamik Panel Veri Analizi ile İncelenmesi. Türk Turizm Araştırmaları Dergisi, 2019; 3(4): 1228-1243.

[25] Goods C. Climate Change and Employment Relations. Journal of Industrial Relations, 2017; 59(5): 670-679.

[26] Fankhauser S, Sehlleier F, Stern N. Climate Change, Innovation and Jobs. Climate Policy, 2008; 8(4): 421-429.

[27] Alagidede P, Adu G, Frimpong P. The Effect of Climate Change on Economic Growth: Evidence from Sub-Saharan Africa. Environ Econ Policy Stud, 2016; 18: 417-436.

[28] Knight KW, Schor Juliet B. Economic Growth and Climate Change: A Cross-National Analysis of Territorial and Consumption-Based Carbon Emissions in High-Income Countries. Sustainability, 2014; 6(6): 3722-3731.

[29] Akram N, Gulzar A. Climate Change and Economic Growth: An Empirical analysis of Pakistan. Pakistan Journal of Applied Economics, 2013; 23(1): 31-54.

[30] Ceesay E, Ndiaye MB. Climate Change, food Security and Economic growth Nexus in the Gambia: Evidence from an Econometrics Analysis. Research in Globalization, 2022; 5: 1-11.

[31] Nawaz A, Siddique H, Majeed M. The Impact of Climate Change on Economic Growth: A Panel Data Analysis. Bulletin of Energy Economics, 2016; 4(4): 359-365.

[32] Dell M, Jones B, Olken B. Climate Shocks and Economic Growth: Evidence from the Last Half Century. American Economic Journal: Macroeconomics, 2008, 4(3), 66-95.

[33] Bernauer T, Koubi V, Kalbhenn A, Ruoff G. Climate Change, Economic Growth, and Conflict. Berlin Conference on Human Dimensions of Global Environmental Change 2010, Berlin, 2010.

[34] Belford C, Delin H, Ceesay E, Ahmed Y, Jonga R. Climate Change Effect on Economic Growth: Mixed Empirical Evidence. International Journal of Human Capital in Urban Management, 2020; 5(2): 99-110.

[35] Kara E, Diken A. Climatic Change: The Effect of Rainfall on Economic Growth. Süleyman Demirel University Visionary Journal, 2020; 11(28): 665-679.

[36] Belford C, Delin H, Ceesay E, Ahmed Y, Sanyang L, Jonga R. The impact on climate change on economic growth based on time series evidence, 1960-2016. Internatioal Journal of Human Capital in Urban Management, 2020; 5(4): 305-318.

[37] Dumrul Y, Kılıçaslan Z. Economic impacts of climate change on agriculture: Empirical evidence from ARDL approach for Turkey. Journal of Business Economics and Finance, 2017; 6(4): 336-347.

[38] Gülbahar O. (2008). Küresel Isınma, Turizme Olası Etkileri ve Türkiye. KMU İİBF Dergisi, 2008; 10(15): 161-162.

[39] Başoğlu A. Küresel İklim Değişikliğinin Ekonomik Etkileri. KTÜ Sosyal Bilimler Enstitüsü Dergisi, 2014; (7): 175-196.

[40] EDGAR. Emissions Database for Global Atmospheric Research, 2022. https://edgar.jrc.ec.europa.eu/ (11.04.2023).

[41] Işık S. Ekonomi-Doğa Çatışmasına Bir Çözüm Olarak Yeşil Yeni Düzen. PhD Thesis, Bursa Uludag University, 2022.

[42] Barbier EB. Global Governance: The G20 and a Global Green New Deal 2010. Economics: The Open-Access, Open-Assessment E-Journal, 2010; 4(2010-2).

[43] Tekin Z. Sosyal bilimlerde güncel konular ve multi-disipliner yaklaşımlar, İklim Değişikliği ile Mücadelede Yeşil İnovasyon Yönetimi, Gökhan Ofluoğlu, İKSAD Uluslararası Yayınevi, Ankara, 2020.

[44] Leenders M, Chandra Y. Antecedents and consequences of green innovation in the wine industry: The Role of channel structure. Technology Analysis & Strategic Management, 2013; 25(2): 203-218.

[45] Chen YS. LBT. The influence of green innovation performance on corporate advantage in Taiwan. Journal of Business Ethics, 2006; 67(4): 331-339.

[46] Kemp R, Pearson P. Final report MEI project about measuring eco-innovation. UM Merit, Maastricht, 2007; 10(2): 1-120.

[47) Intergovernmental Panel on Climate Change. Climate Change 2022: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, UK and New York, 2022.

[48] OECD. Aligning Policies for a Low-carbon Economy, OECD Publishing, Paris, 2015.

http://dx.doi.org/10.1787/9789264233294-en

[49] CBDDO (Presidential Digital Transformation Office), Yeşil Teknolojiler. 2023. https://cbddo.gov.tr/SharedFolderServer/Genel/2..%20Aras%CC%A7t%C4%B1rmaRaporu-Yes%CC%A7ilTeknolojiler.pdf (Accessed April, 2023).

[50] Howes S, Dobes L. Climate change and fiscal policy : A report for APEC. Washington DC: World Bank, East Asia and Specific Region: Office of the Chief Economist, 2011.

[51] WEF R, Brende B, Botwright K. Accelerating cecarbonization through trade in climate goods and services. World Economic Forum, 2022. https://www3.weforum.org/docs/WEF_Accelerating_Decarbonization_through_Trade_2022.pdf

[52] UEF. *Universal Ecological Fund*. The Truth Behind the Climate Changes, 2019. https://feu-us.org/wp-content/uploads/2021/07/The-Truth-Behind-the-Climate-Pledges.pdf (Accessed April, 2023).

[53] World Energy Council. World Energy Trilemma Index 2021. United Kingdom, 2021.

[54] Scholten DC. An energy transition amidst great power rivalry. Journal of International Affairs, 2019-2020; 73(1): 195-204.

[55] OECD. Energy and Climate Policy: Bending the Technological Trajectory, OECD Studies on Environmental Innovation, OECD Publishing, 2012. (Accessed April, 2023). https://read.oecd-ilibrary.org/environment/energy-and-climate-policy_9789264174573-en

[56] MIT Technology Review Insights. The Green Future Index. MIT Technology Review, 2022. https://mittrinsights.s3.amazonaws.com/GFI22report.pdf (Accessed March, 2023).

[57] WB. World Bank. 2022. https://data.worldbank.org/indicator/NY.GDP.MKTP.KD.ZG (Accessed April, 2023).

[58] FAOSTAT. Food and Agriculture Organization of the United Nations, 2023.

[59] WB. World Bank. World Bank Climate Change Knowledge Portal, 2023. (Accessed April, 2023).

[60] UNDP. UNDP Human Development Reports, 2022.

[61] Hsiao C. Analysis of panel data. Cambridge University Press, Cambridge, 2003.

[62] Frees EW. Longitudinal and panel data analysis and applications in the social sciences. Cambridge University Press, New york, 2004.

[63] Yerdelen Tatoğlu F. Panel veri ekonometrisi stata uygulamalı, Beta Publishing, 6. Press, İstanbul, 2021.

[64] Yerdelen Tatoğlu F. İleri panel veri analizi stata uygulamalı. Beta Publishing, 2. Press, İstanbul, 2013.

[65] Brown CH, Clement CR, Epps PL, Wichmann S. The paleobiolinguistics of domesticated chili pepper (Capsicum spp.). Ethnobiology Letters, 2013; 4: 1-11.

[66] Ali SN. Climate change and economic growth in a rain-fed economy: How much does rainfall variability cost Ethiopia? EEA Working Paper Series, 2012; 1-37.

[67] Akram N. Is climate change hindering economic growth of Asian economies? Asia-Pacific Development Journal, 2012; 19(2):1-18.

[68] Kotz M, Levermann A, Wenz L. The effect of rainfall changes on economic production. Natureresearch, 2022; 601(7892): 223-227.