6. EFFECTS OF CLIMATE CHANGE ON ECONOMIC GROWTH: EVIDENCE FROM 20 BIGGEST ECONOMIES OF THE WORLD

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Abstract

This study empirically examines the symmetric and asymmetric effects of climate change measured by temperature and precipitation variables and six other indicators on economic growth in the top 20 economies in the world (WTE-20-in terms of nominal Gross Domestic Product), over the period from 1990 to 2016. Based on the extension of the Cobb-Douglas production function (CDPF), the study uses linear and nonlinear procedures within the scope of new-generation panel data analysis that takes into account the cross-sectional dependence. Regardless of which approaches are used to explain the climate regime, the evidence from this study indicates that climate change has negative and statistically significant effects on economic growth. Therefore, along with the development of climate change adaptation policies, the collaboration under the leadership of the WTE-20 countries to reduce greenhouse gas emissions and thereby prevent the temperature increases should be improved to minimize the negative effects of climate change on growth performances in these countries.

Keywords: climate change, economic growth, panel data analysis, cross-sectional dependence, Cobb-Douglas production function, the Top 20 economies in the world

JEL Classification: Q54, O44, C33.

1. Introduction

Climate change defined as the changes in the climate regime over a time period due to natural variabilities and human activities (Intergovernmental Panel on Climate Change IPCC, 2007) is considered to be one of the most important environmental problems since it has negative socio-economic effects on the global economy. Both nature-induced and

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human-induced factors cause changes in temperature and precipitation values in the climate regime. Especially human-induced activities cause an increase in greenhouse gas emissions, and as a result of this, an increase in temperature values. Regarding climate change, the Paris Agreement[3] and the Special Report on Global Warming of 1.5 °C[4] by the Intergovernmental Panel on Climate Change (IPCC) have focused on temperature increases (UNFCCC, 2020; IPCC, 2018). Also, unexpected severe and frequent weather events due to the change in average temperature and precipitation values and excessive volatility in the climate regime affect the number of production factors and their productivity and change the increasing trend of production (World Bank, 2010). This situation can affect economic growth since it is a concept related to the long-term increase in production capacity. Within this context, the effects of climate change on economic growth take place through direct effects on production factors based on natural resources as well as indirect effects on production factors based on physical and human capital accumulation. The former results from the fact that climate is involved in the production process as a natural factor, while the latter arises because changes occurring in the climate as a result of production and consumption activities affect other production factors (Ekbom and Dahlberg, 2008).

The degree to which countries are affected by climate change varies depending on their level of development. The fact that underdeveloped and developing countries are more affected by climate change is attributed in the literature to the fact that these countries cannot bear the cost of reducing the effects of climate change. It is observed that in these countries climate change negatively affects economic growth due to the decrease in productivity and efficiency in the agricultural sector, which includes labor-intensive technology. While economic growth is realized in developed countries due to the increase in the use of capital-intensive technology, the cost of efforts to reduce the pressure on climate through waste emissions negatively affects economic growth (Jackson, 2009). As is known, total factor productivity (TFP) and physical and human capital accumulation are important for long-term economic growth. It has recently been assumed that climate change affects total factor productivity growth. Considering the importance of TFP for long-term economic growth, Letta and Toll (2019) have directly examined the nature of the relationship between annual temperature shocks and TFP growth rates for the period of 1960-2006, using macro TFP data. At the end of the study, they have stated that an increase of only 1 °C in annual temperature values reduced TFP growth rates by 1.1-1.8%. Besides, Fankhauser and Tol (2005) have argued that climate change can affect labor supply, capital depreciation, and productivity (rather than increasing productivity). TFP represents a combination of labor and capital efficiency, which, as is commonly known, explains the increase in total production, not due to labor and capital inputs, and has traditionally been viewed as a rough measure of technological progress. Therefore, considering the importance of labor and physical capital for long-term economic growth, TFP is taken into account when examining the impact of climate change on economic growth. Based on these explanations, achieving sustainable economic growth in the long term requires estimating the links between economic growth

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[3] *"The Paris Agreement's central aim is to strengthen the global response to the threat of climate change by keeping a global temperature rise this century well below 2 degrees Celsius above pre-industrial levels and to pursue efforts to limit the temperature increase even further to 1.5 degrees Celsius."*

[4] *"An IPCC special report on the impacts of global warming of 1.5 °C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty."*

and climate change (Alagidede, 2016). For this estimation, it is taken to notice TFP and labor and physical capital accumulations.

This study contributes to the literature on the effects of climate change on economic growth in the following ways. Firstly, the 20 biggest economies (WTE-20) in the world (in terms of nominal Gross Domestic Product figures), which are located in different continents, were econometrically examined for the 1990-2016 period within the scope of the new generation panel data methodology. This motivation of the research differs from other studies on the subject. WTE-20 countries can reflect the possible effects of climate change as they are located in different climate regimes in different continents around the world. It is thought that the present study can provide realistic information about the possible effects of climate change since it covers the countries where approximately 3/4 (Worldbank, 2020) of global production activities (GDP) take place. Because the most important effects of climate change are expected to occur in terms of production and subsequent consumption activities. Secondly, the paper explained the climate regime with temperature-precipitation variables and six different indicators related to them. The paper used the extension of the CDPF and linear and nonlinear procedures within the scope of new-generation panel data analysis that takes into account the cross-sectional dependence. Thus, the results were evaluated with both linear and nonlinear model estimates. Within this respect, this study aimed to empirically evaluate whether the anticipated contractionary effects of climate change are experienced on the general economic growth performances of WTE-20 countries, which potentially represent the world-wide state in terms of development level and climate regimes. In this respect, the findings of the study, conducted considering the WTE-20 countries, are expected to contribute to the relevant literature in terms of the chosen country group by using comprehensive climate change indicators and the adopted econometric method.

The rest of the paper is structured as follows: Section 2 reviews the literature. Section 3 gives notice of data sources, model specification, and estimation strategy. Section 4 provides the empirical results and discussion, while Section 5 presents the robustness check. Section 6 concludes the paper by providing some policy implications and suggestions for further research.

2. Literature Review

The effects of climate change on sectors such as agriculture, animal husbandry, and tourism, which have a share in economic growth, have been the subject of research in many studies (Seo *et al*., 2005; Allison *et al*., 2009; Iglesias *et al*., 2009; Lee *et al*., 2012; Steiger *et al*., 2019; Tullo *et al*., 2019). Also, in some studies, the effects of climate change on economic growth are discussed globally or regionally (Fankhauser and Tol, 2005; Mendelsohn, 2005; Mendelsohn *et al*., 2006; Stern, 2006; Eboli *et al*., 2010; Victor, 2012; Kolev *et al*., 2012; Dell *et al*., 2012; Bosello *et al*., 2012; Abidoye and Odusola, 2015; Alagidede *et al*., 2016; Moore and Diaz, 2015; Tol, 2018).

Dell *et al*. (2012) have tried to determine the effects of fluctuations in temperature in countries on total economic results. As a result of the study, they have argued that high temperatures significantly reduced economic growth in poor countries, while higher temperatures reduced not only output levels but also growth rates. They have also highlighted that high temperatures had far-reaching effects that reduced agricultural production, industrial production, and political stability. Fankhauser and Toll (2005) have investigated the dynamic effects that link both climate change and economic growth both theoretically and numerically. They have claimed that the main dynamic effect was through the accumulation of capital. They have stated that a second dynamic effect was related to savings. As a result of their work, they have explained that climate change does not affect growth only through effects on savings and capital accumulation. Eboli *et al*. (2010) have stated that greenhouse gases due to human activity depend on the level of economic activities and emission intensity, and therefore most climate change studies are based on economic growth models and scenarios. However, they have mentioned that economic growth will also be affected by the effects of climate change. Akram (2012) has analyzed the effects of climate change on economic growth for selected Asian countries in the period of 1972-2009. They have developed a growth model with the inclusion of temperature and precipitation as climate change agents in the production function. To predict the model, they have used the fixed-effects model (FEM) and seemingly unrelated regression (SUR). The authors have concluded that increases in temperature, precipitation, and population negatively affect economic growth and that urbanization and human development encourage economic growth. Dellink *et al*. (2014) have focused on the effects of climate change on economic growth. They have evaluated the macroeconomic and sectoral level results of selected climate change impacts in various world regions with simulations made with OECD's dynamic global general equilibrium model ENV-Linkages. Abidoye and Odusola (2015) have examined the empirical link between economic growth and climate change in Africa. They have proven that climate change has a negative impact on economic growth by using annual data for 34 countries from 1961 to 2009. The authors have concluded that an increase of 1 °C in temperature decreased GDP growth by 0.67 points. Colacito *et al.* (2015) have used dynamic panel data models to study the impact of weather on RGDP growth rates. Alagidede *et al*. (2016) have examined the impact of climate change on sustainable growth for Sub-Saharan Africa country panels using panel cointegration modeling techniques. Du *et al.* (2017) have investigated the relationship between temperature and growth within the United States and the European Union. They have found that above the optimal temperature, projected temperature rises have a significantly negative impact on the economic growth of the United States and the European Union. Ogbuabor and Egwuchukwu (2017) have examined the impact of climate change on the overall growth of the Nigerian economy using the Ordinary Least Squares (OLS) prediction technique and data from 1981 to 2014. The authors have found that carbon emissions negatively affect both long-term and short-term growth. Sequeira *et al.* (2018) have stated that their study is based on an assessment of the impact of climate change (*i.e.,* long-term changes in temperature and precipitation) on economic and industrial outputs. Tol (2018), has found that climate change effects on the total economic are negative, but tolerable on average. Kahn *et al.* (2019) have examined the long-term impact of climate change on economic activity in 174 countries for the 1960-2014 period. Their study used a stochastic growth model and a panel data set (temperature and precipitation). As a result, the authors have found that the real output growth per capita is adversely affected by permanent changes in temperature above or below its historical norm and precipitation causes no statistically significant effect. Taher (2019) has examined the relationship between climate change and economic growth in Lebanon. According to the OLS technique, the author has used a time series analysis for the 1990-2013 period. He has explained climate change by using climate factors such as precipitation, forest areas, and carbon emissions. Henseler and Schumacher (2019) have investigated the impact of weather on countries' GDP and their main components of production, namely total factor productivity, capital stock, and employment. Their study has included 101 country-wide services for 1961-2010 of the panel data set. They showed that the main effects of weather are caused by temperature and trigger growth in GDP. They have also found that poorer countries are affected by higher temperature levels more than rich countries.

The present study differs from other studies in the literature as it both considered the WTE 20 countries in different continents of the world and provided linear and nonlinear results together with the methods used.

3. Data and Methodology

In this study, the effects of climate change on the economic growth of WTE-20 countries[5] were econometrically examined for the 1990-2016 period on an annual basis. The beginning of the examination period was set as the year 1990 due to the fact that some of the economic variables used in the estimation of the defined models are available in the databases of the relevant countries. The reason why the data until 2016 was used is that from the CCKP database of WTE-20 countries, climate data are available as time series until 2016. In other words, the CCKP database is the only source that gives time series as other sources provide climate data on a continental basis. In the study, variables attained through standard deviation and moving average calculations of annual average temperature and precipitation values were used for the change in the climate regime, which is considered to be consisting of the aforementioned values that are parallel to other studies in the literature. Furthermore, calculation methods of various international organizations that conduct research on climate change, such as National Aeronautics and Space Administration (NASA), National Oceanic and Atmospheric Administration (NOAA), and Carbon Dioxide Information Analysis Center (CDIAC), were taken as references in attaining such variables indicating the change in the climate regime. Table 1 presents the variables used in the models created to research the physical-human capital accumulation and technological level of WTE-20 countries, the effects of variables indicating climate change on economic growth, and sources of such variables.

PCRGDP, one of the variables in Table 1, was taken from the WB database in real values (with 2010-based prices) and USD for all countries covered in the study. The RGFCF variable was attained as per capita values for all countries covered in the study by calculating the ratio of real fixed capital investment series taken from the WB database with 2010-based prices and in USD to the midyear total population series taken from the same database.

Since fixed capital investment series of Saudi Arabia are not provided in the real form in the WB database for the 1990-1999 period, the data in question was taken nominally (USD) and used after converting into the real form using the GDP deflator of the country. EL variable was attained for all countries covered in the study by calculating the ratio of employed workforce series taken from the TED database in per mille to the midyear total population series taken from the same database. Temperature (TEMP) and precipitation (PREC) variables were established by calculating the average of monthly temperature values in centigrade degrees (°C) and the average of twelve-month precipitation values in millimeters (mm), which are calculated for the 1901-2016 period, and the area between two 0.5*0.5

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[5] *In determining the 20 economically largest countries of the world, the classification made by the World Bank using the 2016 nominal GDP (USD) values has been taken as a reference. These 20 largest economies are, according to the 2016 nominal GDP values; USA, China, Japan, Germany, United Kingdom, France, India, Italy, Brazil, Canada, South Korea, Russia, Spain, Australia, Mexico, Indonesia, Turkey, Netherlands, Switzerland, and Saudi Arabia.*

degrees' latitude and longitude (for an area in approximately 55km*55km range) in the CCKP database.

Table 1

Identification of the Variables Used in the Models

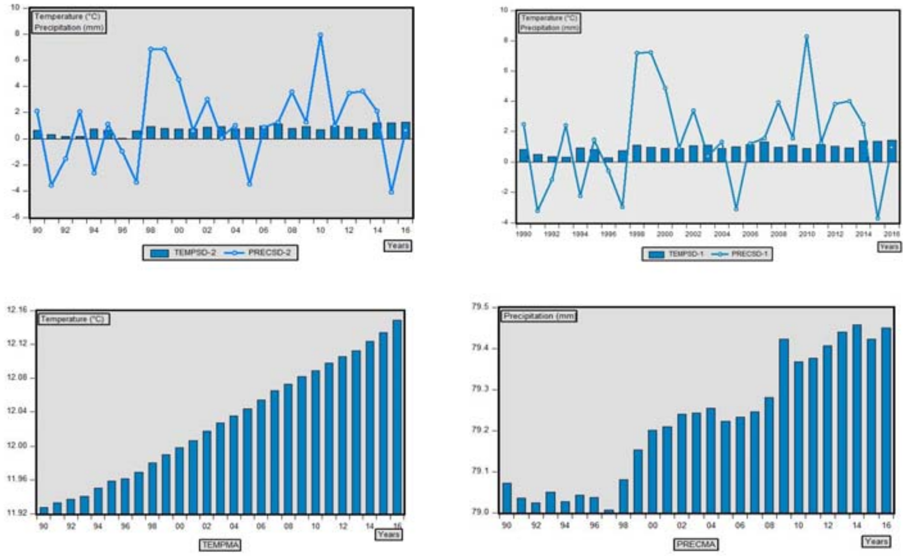
Studied Period: 1990-2016	Number of Cross Sections Forming the Panel: 20	
Abbreviations of Variables	Definitions of Variables	Data Sources of Variables
PCRGDP	Real GDP Per Capita (2010-USD).	WB-The World Bank (World Development Indicators-WDI-2020).
RGFCI	Real Fixed Capital Investment (2010-USD).	
EL	Employed Workforce	The Conference Board (Total Economy Database-TED Original Version, May 2017).
TFP	Total Factor Productivity	
TEMP	Annual Average Temperature Values	The World Bank Group Climate Change Knowledge Portal-CCKP, (Climatic Research Unit (CRU) of University of East Anglia (UEA)).
PREC	Annual Average Precipitation Amounts	
TEMPSD-1	Change in the Annual Average Temperature Values (1901-1990)	The World Bank Group Climate Change Knowledge Portal-CCKP, (Climatic Research Unit (CRU) of University of East Anglia (UEA)) Data and Calculations of authors.
PRECSD-1	Change in the Annual Average Precipitation Amounts (1901-1990)	
TEMPSD-2	Change in the Annual Average Temperature Values (1901-2016)	
PRECSD-2	Change in the Annual Average Precipitation Amounts (1901-2016)	
TEMPMA	Moving Average of Annual Average Temperature Values	
PRECMA	Moving Average of Annual Average Precipitation Amounts	
Note:	*Variables described in the table, such as PCRGDP, RGFCI, EL and TFP, are used with the annual growth rate values within the studied period, and all other variables used to represent the climate change are used with level values in the analyses*.	

The methods used in converting the climatic variables described in Table 1 can be explained as follows. While establishing the TEMPSD-1 and TEMPSD-2 variables, primarily the 90-year and 116-year average values of the TEMP variable in the 1901-1990 and 1901-2016 periods, respectively, were calculated. Afterward, TEMPSD-1 and TEMPSD-2 variables were established by subtracting the 90-year and 116-year annual average temperature values calculated for the 1901-1990 and 1901-2016 periods from the annual average temperature values in the 1990-2016 period (by calculating the standard deviation). The variables of PRECSD-1 and PRECSD-2, which show the changes in annual average precipitation values, were calculated by using the average values of the annual PREC variable (annual average precipitation values) in the 1901-1990 and 1901-2016 periods, respectively. The method of calculating these variables is similar to the TEMPSD-1 and TEMPSD-2 variables described above.

The TEMPMA variable, indicating the moving average of the annual average temperature values, is calculated as moving average for 1990 and following years (1990-2016 period) by using the values of 1901 and all the following years of the TEMP variable (annual average temperature values), created annually for the 1901-2016 period. The PRECMA variable, indicating the moving annual average precipitation values, was calculated as moving average for 1990 and the following years (1990-2016 period) by using the values of 1901 and all the following years of the PREC variable (annual average precipitation values), created annually for the 1901-2016 period. The fact that TEMP and PREC data are available in the CCKP database starting from the year 1901 was effective in determining the year 1901 as the starting year for variables such as TEMPSD-1, TEMPSD-2, PRECSD-1, PRECSD-2, TEMPMA, and PRECMA, which indicate the climate change. Additionally, since global discussions on climate change started only after the 1990s and 1990 is considered to be an important year regarding the issue, the 1901-1990 period temperature (TEMP) and precipitation (PREC) values in the CCKP database were determined as the base for variables such as TEMPSD-1 and PRECSD-1. It is stated in the United Nations Framework Convention on Climate Change that during the 1980s, scientific evidence regarding the association of greenhouse gas emissions caused by human activities with the global climate change increased the concerns of the public opinion. And in 1990, the United Nations General Assembly decided that the Intergovernmental Negotiating Committee (INC) shall be established for the Framework Convention on Climate Change (UNFCCC, 2002). In line with these statements, average values of the variables used by WTE-20 countries as a representation of climate change, calculated in relation to the course of development in the 1990-2016 period, are presented in Figure 1.

Figure 1

Change in the Annual Average Temperature Values and Precipitation Amounts



Source: CCKP Data and Calculations of Authors.

It shows that the climate change data (TEMPSD-1, TEMPSD-2, PRECSD-1, PRECSD-2, TEMPMA, and PRECMA) in the WTE-20 countries have been in an uptrend starting from 1990. Furthermore, it can also be observed that such uptrend in the climate change variables is even greater according to the TEMPMA and PRECMA variables, calculated as moving averages. These results indicate that climate change in WTE-20 countries, calculated through the standard deviations and moving averages of annual average temperature values and annual average precipitation values, has reached to a certain point as of the studied period (regardless of the measurement method and indicator representation). Such changes experienced in the temperature and precipitation values are also stated in other studies conducted similarly (Lee *et al.*, 2012; Abidoye and Odusola, 2015; Guemide, 2017).

4. Empirical Results and Discussion

In this study, econometric models to be estimated to examine the effects of climate change on economic growth in the WTE-20 countries were created by expanding the Cobb-Douglas production function (CDPF). Within this context, the CDPF can be expanded so that it includes the effects of technological development level, which indicates the climate regime and capital accumulation, on economic growth, and can be written as follows:

$$\mathrm{y_{it}} = \mathrm{A_{it}K_{it}^{\alpha}L_{it}^{\tau}C_{it}^{\gamma}e^{\varepsilon_{it}}}, \tag{1}$$

where: (ε_{it}) in the equation determines the factor of error, (i) and (t) represent the countries and the time, respectively. Included in the production function; (y_{it}) shows economic growth (per capita real GDP), (A_{it}) shows the technological development level, (K_{it}) shows the physical capital accumulation (real fixed capital investments), (L_{it}) indicates the human capital accumulation (number of employed persons), and (C_{it}) shows the climate regime, consisting of two subcomponents, namely the annual average temperature levels and annual average precipitation values (Alagidede *et al.*, 2016: 423). In consideration of the evolution of economical growth theories in terms of explaining the economic growth process and technological development level, it is accepted that the technological development level consists of (A_{it}) total factor productivity-TFP. Thus, it is assumed that the TFP, which constitutes the part of economic growth that cannot be explained with the changes in production factors such as physical and human capital accumulation, indicates the production increases in terms of Solow growth only when provided due to technological development (Solow, 1956). Within the scope of these assumptions, the climate regime, consisting of annual temperature values (TEMP) and annual average precipitation values (PREC), and the technological development level, consisting of TFP increases, in the CDPF can be expanded and written, respectively, as follows:

$$A_{it} = f(TFP)_{it}^{\partial} \tag{2}$$

$$C_{it}^{\gamma} = f(TEMP)_{it}^{\theta}(PREC)_{it}^{\vartheta} \tag{3}$$

In accordance with these explanations, as expanded, the CDPF model defined in Equation 1 to be econometrically predicted can be written as follows:

$$y_{it} = \mathrm{\beta_{it}}+\alpha_{it}K_{it}+\tau_{it}L_{it}+\partial_{it}TFP_{it} + \theta_{it}TEMP_{it} + \vartheta_5 PREC_{it} + \varepsilon_{it} \tag{4}$$

Identification of the econometric models through the expansion of the CDPF so that it involves other potential determinants of economic growth are often used in the empirical literature (Barro, 1991; Levine and Renelt, 1992; Sala-i-Martin, 1997; Temple, 2000; Rodrik, 2012; Alagidede *et al.*, 2016). In the study, to determine the effects of climate change on economic growth, the model defined in Equation 4 was examined utilizing the panel data analysis methodology, as the time series of WTE-20 countries were used collectively. Furthermore, as the effects of climate change on the economic growth of WTE-20 countries were examined with climate variables of different properties in this study, alternative variations of the model defined in Equation 4 were predicted to avoid multicollinearity problems and obtain more consistent results. Econometric models, different variations of which will be predicted within the scope of the new generation panel data analysis methodology, which takes into consideration the cross-sectional dependence (CSD) to examine the long-term effects of climate change on the economic growth of WTE-20 countries, are defined by the following equations:

Model-1: $PCRGDP_{it} = \alpha_{\mathrm{it}} + \beta_1 RGFCF_{it} + \beta_2 EL_{it} + \beta_3 TFP_{it} + \beta_4 TEMP_{it} + \varepsilon_{it}$ (5)

Model-2: $PCRGDP_{it} = \alpha_{\mathrm{it}} + \delta_1 RGFCF_{it} + \delta_2 EL_{it} + \delta_3 TFP_{it} + \delta_4 PREC_{it} + \varepsilon_{it}$ (6)

Model-3: $PCRGDP_{it} = \alpha_{\mathrm{it}} + \vartheta_1 RGFCF_{it} + \vartheta_2 EL_{it} + \vartheta_3 TFP_{it} + \vartheta_4 TEMP_{it} + \vartheta_5 PREC_{it} + \varepsilon_{it}$ (7)

In the models, (α) represents the fixed parameters, (β), (δ) and (ϑ) represent slope parameters, (ε) represents errors, and (i) and (t) represent the cross-section units in the panel and the time dimension of the panel, respectively. Stationarities of series in the panel data methodology are of importance, as analyses on non-stationary series may result in inconsistent t, F, and R^2 test statistics. Hence, to avoid the spurious regression phenomenon and obtain consistent results in the panel data studies, stationarity of series must be examined in particular (Tatoglu, 2013:199). The unit root tests, which are used to determine the stationarity of the panel data, have two subcategories as the first and second generation, depending on whether there is a cross-sectional dependence in the unit creating the panel. It is assumed that in the first- and second-generation panel unit root tests, cross-sections are independent of and dependent on each other, respectively. While it is assumed in the first generation panel unit root tests that a shock occurring in one of the sections affects all units equally, in the second generation panel unit root tests, it is accepted that each unit is affected differently by the shock that occurs in one of the sections forming the series. However, in cases that there is a cross-sectional dependence between the units creating the panel, the first generation panel unit root tests (Hadri, 2000; Levin *et al.*, 2002; Im *et al.*, 2003, etc.) do not give consistent results; so, second generation panel unit root tests can be used (Taylor and Sarno 1998; Breuer *et al.*, 2002; Pesaran, 2007; Palm *et al.*, 2011; Hadri and Kurozumi, 2012; Pesaran *et al.*, 2013, etc.) to obtain more reliable results. Therefore, prior to the estimation of models established in panel data analyses, the CSD in the series/co-integration equation in the model must be examined, and the unit root that needs to be used in the analyses, as well as other tests, must be determined. When this condition is not taken into consideration, tests may not yield reliable results (Menyah *et al.*, 2014: 390-91).

Additionally, while researching the CSD in panel data, time and section dimensions of the panel must be supervised and when time dimension is bigger than the section dimension, (T>N), Breusch ve Pagan (1980) CD-LM1 test can be used and when time dimension equals to the section dimension (T=N) and time dimension is smaller than the section dimension (T<N), Pesaran (2004) CD-LM2 test can be used. CD-LM1 and CD-LM2 tests are calculated based on the equation stated in Equation 8.

$$\text{CD–LM} = \breve{\rho}_{ji} = \frac{\sum_{t=1}^{T} e_{it}\, e_{jt}}{\left(\sum_{t=1}^{T} e_{it}^{2}\right)^{1/2}\left(\sum_{t=1}^{T} e_{jt}^{2}\right)^{1/2}} \tag{8}$$

In Equation 8, while ($\breve{\rho}_{ji}$) shows the correlation between the error series, (e_{it}) represents the error series obtained from each unit for t number of observations as long as i=1, n with the least-squares method. However, CD-LM1 and CD-LM2 tests, which may show deviant results when the group average is zero and the unit average is different than zero, can be expanded with the CD-LM test (Pesaran *et al.*, 2008), which is attained by adding the average (μ_{Tij}) and variance (υ_{Tij}) of the cross sections CD-LM$_{adj}$ to the test statistics:

$$CD\text{–}\mathrm{LM}_{\mathrm{Adj}} = \mathrm{NLM}^{**} = \sqrt{\frac{2T}{N(N-1)}}\left(\sum_{i=j}^{n-1}\sum_{j=i+1}^{n}\frac{(\mathrm{T}-\mathrm{K})\breve{\rho}_{ij}^{2} - \mu_{\mathrm{Tij}}}{\upsilon_{\mathrm{Tij}}}\right) \tag{9}$$

CD-LM$_{adj}$ test statistic can show more consistent results in cases that the group average is zero and the unit average is different than zero when compared to CD-LM1 and CD-LM2 test statistics. This test, also called the adjusted CD-LM test, can use the time and section dimensions of the series creating the panel under all alternative conditions (Pesaran et al., 2008: 105-127). On the other hand, the existence of cross-section dependence in CD-LM tests is researched with an alternative hypothesis of "there is a cross-section dependence in the series or model," as opposed to the "there is no cross-section dependence in the series or model" hypothesis. In CD-LM tests, which are assumed to demonstrate a standard normal distribution, in cases that the basic hypothesis is rejected, it is inferred that there is a cross-sectional dependence in the series and/or model. In the study, the existence of cross-section dependence in the series or co-integration equation in the models defined for the WTE-20 countries was examined with the CD-LM1 and CD-LMadj tests, and the results are reported in Table 2.

Table 2 indicates that the probability values of CD-LM test statistics, calculated in Constant or Constant+ Trend forms for all the variables and co-integration equations in the models, are smaller than 0.01. In this case, all the basic hypotheses created for all the variables and co-integration equations in accordance with the CD-LM tests need to be rejected. These results indicate that cross-sectional units in the panel are dependent on the variables and co-integration equations in the models and that new generation panel data methodology test methods, which take into account the existence of the CSD, must be used in further stages of the analyses (Baltagi, 2008).

Table 2

Cross-Sectional Dependence Test Results

Variables	Test Statistics					
	Constant		L	Constant+Trend		L
	CD-LM1	CD-LM$_{adj}$		CD-LM1	CD-LM$_{adj}$	
PCRGDP	933.86***[0.000]	218.82***[0.000]	2	960.87***[0.000]	174.12***[0.000]	2
RGFCI	639.52***[0.000]	139.52***[0.000]	3	620.45***[0.000]	127.14***[0.000]	3
EL	406.10***[0.000]	162.64***[0.000]	3	418.23***[0.000]	176.53***[0.000]	2
TFP	586.91***[0.000]	186.17***[0.000]	2	567.61***[0.000]	180.26***[0.000]	2
TEMP	626.52***[0.000]	178.82***[0.000]	2	530.56***[0.000]	179.15***[0.000]	2
PREC	292.07***[0.000]	191.29***[0.000]	2	304.22***[0.000]	184.95***[0.000]	2
TEMPSD-1	626.52***[0.000]	178.82***[0.000]	2	530.56***[0.000]	179.15***[0.000]	2

Variables	Test Statistics					
	Constant		L	Constant+Trend		L
	CD-LM1	CD-LM$_{adj}$		CD-LM1	CD-LM$_{adj}$	
PRECSD-1	307.78***[0.000]	163.87***[0.000]	3	305.81***[0.000]	156.40***[0.000]	3
TEMPSD-2	626.52***[0.000]	178.82***[0.000]	2	530.56***[0.000]	179.15***[0.000]	2
PRECSD-2	315.74***[0.000]	127.39***[0.000]	4	317.97***[0.000]	124.15***[0.000]	4
TEMPMA	624.46***[0.000]	151.62***[0.000]	3	550.93***[0.000]	156.78***[0.000]	3
PRECMA	584.55***[0.000]	192.12***[0.000]	2	537.20***[0.000]	183.39***[0.000]	2
Model-1	663.19***[0.000]	4.52***[0.000]	2	702.05***[0.000]	7.22***[0.000]	2
Model-2	786.84***[0.000]	2.58***[0.005]		782.15***[0.000]	13.66***[0.000]	
Model-3	657.56***[0.000]	3.74***[0.000]		695.08***[0.000]	5.09***[0.000]	
Model-4	684.55***[0.000]	4.33***[0.000]		727.01***[0.000]	11.83***[0.000]	
Model-5	788.43***[0.000]	2.86***[0.002]		784.13***[0.000]	14.85***[0.000]	
Model-6	680.76***[0.000]	3.79***[0.000]		722.03***[0.000]	9.29***[0.000]	
Model-7	951.81***[0.000]	4.58***[0.000]		944.19***[0.000]	4.58***[0.000]	
Model-8	744.11***[0.000]	4.52***[0.000]		756.03***[0.000]	4.52***[0.000]	
Model-9	983.37***[0.000]	3.50***[0.000]		963.77***[0.000]	3.50***[0.000]	

Note: *"***"indicates that there is Cross-Sectional Dependence in series of 1% importance level, and in the related model. The "L" column in the table shows the optimal lag lengths determined in company with Schwarz information criteria, and the values in square brackets "[]" indicate the probabilities of test statistics.*

In this respect, stationarity of series in the defined models is researched with the CADF (Cross-sectional Augmented Dickey-Fuller) second generation panel unit root test, which takes into account the existence of the CSD and has been developed by Pesaran (2007). In this test, firstly, all the CADF test statistical values are calculated for all the cross-sections creating the panel, then the arithmetic mean of these values are calculated, and the CIPS (Cross-Sectionally Augmented IPS) statistics are determined for the whole panel. CADF test statistics, which have been designed for N>T condition and can yield significant results under N<T condition as well, are calculated as follows:

$$t(N,T) = \frac{\Delta y_i' \overline{\mathrm{M}}_i y_{i-1}}{\overline{\boldsymbol{\sigma}}^2 (\Delta y_{i-1}' \overline{\mathrm{M}}_i y_{i-1})^{\frac{1}{2}}} \tag{10}$$

After the CADF test statistical values in Equation 10 are calculated, the mean of these values is calculated, and the CIPS statistical values are obtained as follows.

$$\mathrm{CIPS} = \mathrm{N}^{-1} \sum_{\mathrm{i}=1}^{\mathrm{n}} \mathrm{t(N,T)} \tag{11}$$

The calculated CADF and CIPS test statistics values are compared to the critical table values created by the Pesaran (2007) Monte Carlo simulations, and the basic hypotheses for stationarity are tested. As a result of the test, if the calculated CADF and CIPS test statistics values are bigger than the critical table values by absolute value, the basic hypothesis (that there is a unit root in the series) is rejected, and the alternative hypothesis (that there is no unit root in the series) is accepted for the whole related unit panel (Pesaran, 2007: 265-312). The stationarity of variables in the models defined in the study is examined by the CADF Panel Unit Root test, and its results are presented in Table 3.

Table 3

CADF Panel Unit Root Test Results

Whole Panel (CIPS) Test Statistics					
Variables		Constant	L	Constant+Trend	L
PCRGDP		-2.80***	2	-2.92***	2
RGFCI		-3.13***	3	-3.22***	3
EL		-2.73***	3	-3.02***	2
TFP		-2.61***	2	-2.74**	2
TEMPSD-1		-2.95***	2	-3.21***	2
PRECSD-1		-3.08***	3	-3.39***	3
TEMPSD-2		-2.95***	2	-3.21***	2
PRECSD-2		-3.02***	4	-3.31***	4
TEMPMA		-3.22***	3	-2.97***	3
PRECMA		-3.16***	2	-3.41***	2
Critical Values	1%	-2.38		-2.88	
	5%	-2.20		-2.72	

Note: *The "***" and "**" indicate that variables are stationary at %1 and 5% significance levels, respectively. CIPS test statistics critical table values according to the T and N conditions have been obtained from the study of Pesaran (2007). Regarding column "L", see: Table 2.*

Table 3 shows that all the variables in the models are stationary at the level value at different significance levels. This is understood from the fact that CIPS statistics values, which are calculated with constant and with constant+trend forms, are bigger than the critical table values at 0.01 or 0.05 significance values by absolute value, and that basic hypotheses are rejected.

After it is determined that all the variables in the defined models are stationary at the level value according to the CADF Panel Unit Root test, stationary condition of series is also examined with the Multifactor Panel Unit Root Test (MPURT), developed by Pesaran *et al*. (2013), to avoid spurious unit root (to determine the consistency of the results). The MPURT test is based on the CSB (Simple Average of Cross-Sectionally Augmented Sargan-Bhargava) Panel Unit Root Test which is constructed by developing CIPS (Cross-Sectionally Augmented Im-Pesaran-Shin) and SB (Sargan-Bhargava) tests to consider the CSD. Unit Root Test (Simple Average of Cross-Sectionally Augmented Sargan-Bhargava) was established by developing the SB test, developed by Sargan and Bhargava (1983), to take into consideration the cross-sectional dependence. CIPS and CSB Panel Unit Root Tests include information of k number of observable time series and m number of nonobservable factors within the multifactor error structure of the cross-sectional units generating the panel, and they also enable removing the autocorrelation arising from the error structure of the common factors in the cross-sections creating the panel.

Thus, in CIPS and CSB Panel Unit Root Tests, a stationarity analysis is performed by taking into consideration the macroeconomic variables such as production, interest rate, inflation rate, unemployment rate, etc., and the effects of common factors that may be influential on the series and cause the CSD, such as technological shocks, financial policies, etc. Statistics of CIPS and CSB Panel Unit Root Test, which can show consistent results and can be used in all conditions between T and N, are calculated as shown in Equations 12 and 13:

$$CIPS^{*}{}_{NT} = N^{-1} \sum_{i-1}^{N} t_i^{*}\,(N,T) \tag{12}$$

$$CSB_{NT} = N^{-1} \sum_{i-1}^{N} CSB_i\,(N,T) \tag{13}$$

Here, (N) indicates the number of cross-sections in the panel, (T) indicates the time dimension of the panel, and $(t_i^{*}(N,T))$ indicates the sampling distribution of the panel. CIPS and CSB test statistic values, calculated as a result of the MPURT Test, are compared with the critical table values, created by Pesaran *et al*. (2013), formed by the stochastic simulation method, and hypotheses are tested for stationarity. If the calculated CIPS and CSB test statistic values are bigger than the critical table values, the basic hypothesis (there is a unit root in the series for all cross-section units creating the panel, or series is not co-integrated) is accepted, and the alternative hypothesis for the series is rejected in the whole panel (Pesaran *et al*., 2013: 96-99). In the study, the stationarity of the series in the models was researched with CIPS and CSB Panel Unit Root Tests, where TEMP, PREC, and PCRDGP series are used as multifactor, which is considered to be influential in the creation of cross-sectional dependence in the series, and the results are reported in Table 4.

Table 4 shows that all the variables in the defined models are in Constant and Constant Trend forms and are stationary at the level value at different significance levels. This can be inferred from the fact that the CIPS and CSB test statistics values are smaller than critical table values at 0.01 or 0.05 significance levels, and that basic hypotheses are rejected. These results suggest that the level value stationarity of variables in defined models is valid even in the cases that TEMP, PREC, and PCRGDP series, which are considered to be influential in creating cross-sectional dependence in the variables, are used as multifactor.

Table 4

Multifactor Panel Unit Root Test Results

Multiple Factors	Variables	Test Statistics				Critical Values			
		Constant							
		CIPS	L	CSB	L	CIPS		CSB	
						1%	5%	1%	5%
TEMP PREC	PCRGDP	-3.45***	3	0.140***	2	-2.47	-2.20	0.144	0.183
	RGFCI	-2.69***	1	0.098**	2	-2.76	-2.54	0.144	0.183
	EL	-2.95***	3	0.163**	2	-2.47	-2.20	0.144	0.183
	TFP	-4.56***	3	0.117**	3	-2.47	-2.20	0.101	0.131
PCRGDP	TEMPSD-1	-2.96***	1	0.080***	2	-2.61	-2.41	0.180	0.223
	PRECSD-1	-2.59***	2	0.115***	2	-2.50	-2.27	0.180	0.223
	TEMPSD-2	-2.67***	1	0.155***	2	-2.61	-2.41	0.180	0.223
	PRECSD-2	-2.50***	3	0.160**	3	-2.43	-2.21	0.141	0.180
	TEMPMA	-5.90***	1	0.012***	1	-2.61	-2.41	0.211	0.257
	PRECMA	-3.30***	1	0.200***	1	-2.61	-2.41	0.211	0.257
TEMP PREC	PCRGDP	-3.85***	1	0.070***	2	-3.25	-3.04	0.093	0.106
	RGFCI	-3.80***	1	0.050***	1	-3.25	-3.04	0.079	0.090
	EL	-3.45***	1	0.070**	2	-3.25	-3.04	0.093	0.106
	TFP	-3.88***	1	0.082***	2	-3.25	-3.04	0.093	0.106
PCRGDP	TEMPSD-1	-2.90**	2	0.065***	2	-2.93	-2.68	0.078	0.089

Multiple Factors	Variables	Test Statistics				Critical Values			
		Constant							
		CIPS	L	CSB	L	CIPS		CSB	
						1%	5%	1%	5%
	PRECSD-1	-2.75**	2	0.055***	2	-2.93	-2.68	0.078	0.089
	TEMPSD-2	-3.69***	1	0.095**	1	-3.06	-2.85	0.088	0.100
	PRECSD-2	-3.45***	1	0.052***	2	-3.06	-2.85	0.078	0.089
	TEMPMA	-4.45***	1	0.007***	1	-3.06	-2.85	0.088	0.100
	PRECMA	-3.59***	1	0.040***	1	-3.06	-2.85	0.088	0.100

Note: *The "***" and "**" indicate that variables are stationary at a 1% and 5% significance levels, respectively. Critical table values for single and double factor CIPS and CSB test statistics have been attained to the studies by Pesaran et al. (2013) in accordance with the T and N conditions. Regarding column "L", see: Table 2.*

Determination of the fact that all the macroeconomic and climatic variables used in the defined models are stationary at the same level value (integrated), also means that there is a long-term balance correlation (co-integration) between the variables (Tari, 2010). Within this context, upon determination of the fact that all the variables in the models defined in this study are stationary at the same level values, variables must be subjected to regression analysis at their stationary levels so that the effects of explanatory variables on economic growth can be examined. However, as CSD is existent in all the models defined in the study, the magnitude of the effects of explanatory variables in the models on economic growth can be examined through estimators that take into consideration the CSD.

In the study, the effects of climate change on economic growth in WTE-20 group countries are researched with the Two-Step Least Squares (TSLS), which can be used in cases of CSD. In the TSLS estimator (developed by Breitung, 2005), based on Vector Error-Correction Model (VECM), long-term coefficients of the independent variables are obtained by allowing the alternation of coefficients in the co-integration equation between the cross-sections creating the panel. In the first digit of the TSLS estimator, firstly the parameters of cross-sections creating the panel are estimated, and in the second digit, long-term parameters of the whole panel are obtained with the expanded least squares method. Breitung (2005) has stated that such parametric estimations by the TSLS method show more effective results, especially in smaller samplings compared to estimations such as FMOLS (Fully Modified Ordinary Least Squares), which modify the internalities in the independent variables through semi-parametric methods. The long-term coefficients of the co-integration equation in the TSLS estimator are calculated based on the following transformed VECM model:

$$\gamma_i'\Delta y_{it} = \gamma_i'\alpha_i\beta' y_{i,t-1} + \gamma_i'\varepsilon_{it} \tag{14}$$

In Equation 14, (ε_{it}) indicates the error vector, and provided that $E(\varepsilon_{it})=0$, the covariance matrix is indicated. In the equation, (α_i indicates the co-integration matrix varying according to the cross-section units, and (β') indicates the co-integration matrix that is common for all the cross-sections creating the panel. In the equation, firstly the (α_i) matrix of the cross-section units forming the panel are separately estimated. Then, using the results from the (α_i) matrix, the system is transformed, and the (β') co-integration matrix for the whole panel is obtained through the panel expanded by the least -squares method (Breitung, 2005:151-55). In the study, alternative models established to identify the effects of climate change on economic growth in the WTE-20 countries were estimated by the Panel TSLS method, and the results are shown in Table 5.

Table 5

Long Termed Co-Integration Coefficients: Results of Panel TSLS

Models	Model-1		Model-2		Model-3	
Variables	Coefficients	SE.	Coefficients	SE.	Coefficients	SE.
RGFCI	0.170***	0.004 [0.000]	0.021***	0.002 [0.000]	0.093***	0.004 [0.000]
EL	0.629***	0.019 [0.000]	0.916***	0.018 [0.000]	0.658***	0.023 [0.000]
TFP	0.624***	0.019 [0.000]	0.660***	0.017 [0.000]	0.557***	0.024 [0.000]
TEMPSD-1	-0.114***	0.047 [0.000]	—	—	-0.299***	0.089 [0.000]
PRECSD-1	—	—	-0.037***	0.002 [0.000]	-0.011***	0.005 [0.000]
Models	Model-4		Model-5		Model-6	
Variables	Coefficients	SE.	Coefficients	SE.	Coefficients	SE.
RGFCI	0.024***	0.002 [0.000]	0.072***	0.004 [0.000]	0.025***	0.002 [0.000]
EL	0.817***	0.032 [0.000]	0.694***	0.027 [0.000]	0.791***	0.032 [0.000]
TFP	0.647***	0.043 [0.000]	0.548***	0.030 [0.000]	0.633***	0.041 [0.000]
TEMPSD-2	-0.259**	0.144 [0.035]	—	—	-0.221***	0.036 [0.000]
PRECSD-2	—	—	-0.011***	0.006 [0.002]	-0.013***	0.005 [0.000]
Models	Model-7		Model-8		Model-9	
Variables	Coefficients	SE.	Coefficients	SE.	Coefficients	SE.
RGFCI	0.058***	0.005 [0.000]	0.051***	0.004 [0.000]	0.094***	0.007 [0.000]
EL	0.740***	0.031 [0.000]	0.793***	0.025 [0.000]	0.625***	0.028 [0.000]
TFP	0.535***	0.038 [0.000]	0.590***	0.031 [0.000]	0.514***	0.041 [0.000]
TEMPMA	-4.293***	0.488 [0.000]	—	—	-3.484***	0.510 [0.000]
PRECMA	—	—	-0.663***	0.097 [0.000]	-0.624***	0.117 [0.000]

Note: *The "***" and "**" indicates that the t- statistics of coefficients are at a 1% and 5% significance levels, respectively. The "SE." term in the table shows the errors of coefficients, and the values between square "[]" brackets indicate the probabilities.*

Panel TSLS results in Table 5 were examined as a whole with regards to the nine models defined for the WTE-20 countries, and it was observed that the coefficients, calculated for all the independent variables in the models, are of similar magnitude and significance levels. This indicates that the models defined in the study were consistently established and that the models resulted in consistent findings.

Table 5 are examined in terms of the independent variables, which serve as the basic determinant of the economic growth, it is observed that coefficients of RGFCI, EL and TFP variables are positive and statistically at a 1% significance level unexceptionally for all models, consistent with the expectations. These results suggest that the increases/improvements in the physical-human capital accumulation and technological development level in the WTE-20 countries affect economic growth positively and in a statistically significant way. Also, it is observed that the magnitude of positive and statistically significant effects of RGFCI, EL, and TFP explanatory variables on the economic growth are EL, TFP, and RGFCI for all the models, respectively. These results suggest that economic growth performances (while other long-term determinant factors of economic growth are constant) of WTE-20 countries for the studied period depend mostly on human capital accumulation, technological development level, and physical capital accumulation, respectively.

Table 5 shows that coefficients of TEMPSD-1, PRECSD-1, TEMPSD-2, PRECSD-2, TEMPMA, and PRECMA variables, which are the climate change independent variables, are negatively and statistically at a 1% or %5 significance level in all models, consistent with the expectations. These results indicate that the changes experienced in the climate regime of WTE-20 countries, in other words, increases in the standard deviations and moving averages of annual average temperature values/annual average precipitation values, affect the economic growth negatively and in a statistically significant way. When Table 5 is investigated in terms of coefficients of such variables, it is seen that, compared to PRECSD-1, PRECSD-2, and PRECMA variables, the magnitude of negative and statistically significant effects of TEMPSD-1, TEMPSD-2, and TEMPMA variables on economic growth is significantly stronger in all models. TEMPSD variables affect economic growth negatively between -0.114 and -0.299 units. In other words, a one-unit increase in the annual average temperature values causes a decrease in economic growth between -0.299 and -0.114 units. PRECSD variables, on the other hand, affect economic growth negatively between -0.011 and -0.037. To be more specific, a one-unit increase in annual average precipitation results in a decline in economic growth approximately between -0.037 and -0.011 units. The Moving Average of Annual Average Temperature Values (TEMPMA) variable also negatively affects economic growth between -4.293 and -3.484 units. It is observed that the Moving Average of Annual Average Precipitation Values (PRECMA) has a negative effect on economic growth between -0.663 and -0.624 units. Results suggest that the effects of climate change, in terms of both temperature and precipitation values, on the economic growth of WTE-20 countries are negative/statistically significant, while indicating that magnitude of such effects is more prominent when considered along with the temperature changes.

When the results of models are examined in terms of the qualities of climate change indicators, the magnitude of the negative/statistically significant effects of variables TEMPMA and PRECMA on economic growth is greater compared to variables TEMPSD-1, PRECSD-1, TEMPSD-2, and PRECSD-2 (Table 5). Briefly, in WTE-20 countries, the effects of standard deviations and moving averages of annual average temperature values and annual average precipitation values on economic growth are negative/statistically significant while this effect is a lot greater when calculated through moving averages. As a result, it has been demonstrated that climate change in terms of both temperature and precipitation (regardless of the measurement method and indicator representation) has had, consistent with the expectations, contractionary effects on economic growth in the WTE-20 countries during the study period.

5. Robustness Check

The study also employs the ARDL (Autoregressive-Distributed Lag) model based on the VECM methodology to confirm the consistency of the findings showing that climate change has a negative effect on economic growth in the WTE-20 group countries. The ARDL model is the model that observes the cross-sectional dependency between panel units and can be used if the variables are stationary (integrated) at the level of [I (1)]. Since the ARDL model uses the lagged values of the variables in the defined models, it allows the possibility of eliminating possible problems due to autocorrelation and internality. However, the consistency of TSLS findings of defined models is investigated separately with linear (L) and nonlinear (NL) ARDL models, which also take into account asymmetric relationships as well as symmetrical relationships between defined model variables. In this paper, the L-ARDL model checked the robustness of TSLS findings, which investigate long-term linear relationships between variables of defined models. Also, with the NL-ARDL model, it was aimed to determine whether long-term linear relationships are valid in case of non-linearity. The panel L-ARDL model (developed by Pesaran ***et al***., 1999), which allows the examination of symmetrical relationships between model variables, is based on the following two-variable regression equation, such as (Y) and (X):

$$\Delta Y_{it} = \alpha_{1t} + \sum_{n=0}^{k} \beta_{1\,2it}\, \Delta X_{it-n} + \delta_{2\,1it} Y_{it-1} + \delta_{2\,2it} X_{it-1} + \varepsilon_{1it} \tag{15}$$

In Equation 15, (Δ) shows the difference processor of variables, $(1 - \sum_{n=1}^{k} \beta e_{it})$ symmetrical error correction term indicates the convergence rate in long-term relationship-ECM, and (α_{1t}) shows the constant term. $(k = 1,2)$ and $(e = 1, \dots m)$; (β_{keit}) ve (δ_{keit}) indicate short and long term coefficients, respectively (Pesaran ***et al***., 1999: 621-634). The Panel NL-ARDL model has been developed by Shin ***et al***. (2014). It is based on the adaptation of the NL-ARDL model to panel data analysis, which allows the examination of symmetrical and asymmetrical relationships between model variables (Salisu and Isah, 2017: 259; Kouton, 2019: 482). The bivariate nonlinear Panel NL-ARDL model, such as (Y) and (X), is based on the following regression equation:

$$\Delta Y_{it} = \alpha_{1t} + \sum_{n=0}^{k} \beta_{1\,2it}\, \Delta X^{+}_{it-n} + \sum_{n=0}^{k} \beta_{1\,3it}\, \Delta X^{-}_{it-n} + \delta_{1\,4it} Y_{it-1} + \delta_{1\,5it} X^{+}_{it-1} + \delta_{1\,6it} X^{-}_{it-1} + \varepsilon_{1it} \tag{16}$$

In Equation 16, $(1 - \sum_{n=1}^{k} \beta e_{it})$ specifies the asymmetric ECM, which indicates the convergence rate to the balance in the long-term relationship. The symbols (+) and (-) show the asymmetric effects of the positive-negative changes in the variable (X) on the variable (Y). In other words, it shows the asymmetrical effects of the variable (X) on the variable (Y) in the short and long term (Shin ***et al***., 2014: 285-290; Salisu and Isah, 2017:262-63). In models in equality 15 and 16, short- and long-term coefficients are calculated by two different estimators, Pooled Mean Group (PMG) and Mean Group (MG), which assume that the cross-section units in the panel are homogeneous and heterogeneous, respectively. It is decided by the Hausman (Chi^2) test, which is one of the estimators that can provide deviant and consistent results from PMG and MG. According to the Hausman (Chi^2) test statistics calculated here, if the probability values are greater than 0.05, the basic hypothesis that "long-term coefficients in the model are homogeneous" is accepted at 5% significance level, and it is decided that the PMG estimator is the best estimator (Pesaran *et al*., 1999: 621-634).

The results of the panel L-ARDL and NL-ARDL model estimated by PMG according to the Hausman (Chi^2) test of the models defined in the study are presented in Table 6 and Table 7, respectively.

Table 6

Results of Panel L-ARDL

Models	**Model-1**		**Model-2**		**Model-3**	
Variables	**Coefficients**	**SE.**	**Coefficients**	**SE.**	**Coefficients**	**SE.**
RGFCI	0.135***	0.015 [0.000]	0.147***	0.010 [0.000]	0.137***	0.015 [0.000]
EL	0.537***	0.050 [0.000]	0.490***	0.035 [0.000]	0.541***	0.049 [0.000]
TFP	0.812***	0.049 [0.000]	0.702***	0.034 [0.000]	0.796***	0.051 [0.000]
TEMPSD-1	-0.266***	0.092 [0.004]	—	—	-0.247**	0.097 [0.011]
PRECSD-1	—	—	-0.003***	0.001 [0.000]	-0.004**	0.002 [0.024]
ECM	-0.519***	0.058 [0.000]	-0.684***	0.072 [0.000]	-0.494***	0.057 [0.000]
C	0.644***	0.122 [0.000]	1.011***	0.300 [0.001]	0.587***	0.115 [0.000]
Chi^2 LL	2.95 [0.567]	-486.56	1.16 [0.885]	-436.58	3.16 [0.675]	-471.98
Models	Model-4		Model-5		Model-6	
Variables	Coefficients	SE.	Coefficients	SE.	Coefficients	SE.
RGFCI	0.135***	0.015 [0.000]	0.148***	0.011 [0.000]	0.136***	0.015 [0.000]
EL	0.537***	0.049 [0.000]	0.491***	0.035 [0.000]	0.541***	0.049 [0.000]
TFP	0.812***	0.050 [0.000]	0.702***	0.034 [0.000]	0.796***	0.051 [0.000]
TEMPSD-2	-0.267***	0.093 [0.004]	—	—	-0.247**	0.097 [0.011]
PRECSD-2	—	—	-0.003***	0.001 [0.000]	-0.004**	0.002 [0.024]
ECM	-0.519***	0.058 [0.000]	-0.684***	0.072 [0.000]	-0.494***	0.057 [0.000]
C	0.612***	0.121 [0.000]	1.011***	0.300 [0.001]	0.560***	0.114 [0.000]
Chi^2 LL	2.95 [0.567]	-486.57	1.16 [0.885]	-436.58	1.56 [0.816]	-471.99
Models	Model-7		Model-8		Model-9	
Variables	Coefficients	SE.	Coefficients	SE.	Coefficients	SE.
RGFCI	0.134***	0.014 [0.000]	0.127***	0.013 [0.000]	0.131***	0.013 [0.000]
EL	0.535***	0.044 [0.000]	0.521***	0.039 [0.000]	0.531***	0.039 [0.000]
TFP	0.775***	0.045 [0.000]	0.767***	0.040 [0.000]	0.763***	0.040 [0.000]

Models	Model-1		Model-2		Model-3	
Variables	**Coefficients**	**SE.**	**Coefficients**	**SE.**	**Coefficients**	**SE.**
TEMPMA	-2.276***	0.581 [0.000]	—	—	-1.258**	0.618 [0.022]
PRECMA	—	—	-0.596***	0.094 [0.000]	-0.361***	0.138 [0.009]
ECM	-0.566***	0.052 [0.000]	-0.581***	0.061 [0.000]	-0.601***	0.058 [0.000]
C	15.095***	2.889 [0.000]	28.878***	4.424 [0.000]	26.966***	3.698 [0.000]
Chi^2 LL	1.36 [0.851]	-478.56	1.37 [0.849]	-479.59	1.90 [0.863]	-465.41

Note: *The "***" and "**" indicates that the t- statistics of coefficients are at a 1% and 5% significance levels, respectively. The "SE." term in the table shows the errors of coefficients, and the values between square "[]" brackets indicate the probabilities. ECM coefficients, which are calculated as negative at 1% significance level in the models, indicate that the effects of short-term shocks among the model variables will disappear in the long term.*

Table 6 shows that the coefficients of the RGFCI, EL, and TFP variables, which are the main determinants of economic growth in all of the defined models, were calculated as positive and statistically significant at a 1% significance level, as expected. On the other hand, it is understood that the coefficients of TEMPSD-1, PRECSD-1, TEMPSD-2, PRECSD-2, TEMPMA, and PRECMA variables, which represent climate change in all of the defined models, are negative and statistically significant at a 1% to 5% significance level, as expected. In the estimation of the models defined, Panel TSLS and L-ARDL findings support each other. The obtained results show that the linear increase in the WTE-20 group has a positive/statistically significant effect on the growth of physical-human capital and technological development, while the linear changes in the climate regime have a negative/statistically significant effect on economic growth.

Table 7

Results of Panel NL-ARDL

Models	Model-1		Model-4		Model-7	
Variables	**Coefficients**	**SE.**	**Coefficients**	**SE.**	**Coefficients**	**SE.**
RGFCI	0.144***	0.011 [0.000]	0.144***	0.011 [0.000]	0.144***	0.011 [0.000]
EL	0.516***	0.035 [0.000]	0.516***	0.035 [0.000]	0.492***	0.035 [0.000]
TFP	0.727***	0.035 [0.000]	0.727***	0.035 [0.000]	0.707***	0.034 [0.000]
$TEMP^+$	-0.229**	0.103 [0.026]	-0.229**	0.102 [0.026]	-12.715**	5.541 [0.022]
$TEMP^-$	-0.134	0.098 [0.174]	-0.133	0.098 [0.174]	-13.795	23.628 [0.559]
ECM	-0.709***	0.077 [0.000]	-0.708***	0.077 [0.000]	-0.703***	0.075 [0.000]
C	0.981***	0.328 [0.003]	0.980***	0.328 [0.003]	0.930***	0.327 [0.004]
Chi^2 LL	2.26 [0.813]	-431.53	2.26 [0.813]	-431.52	1.98 [0.372]	-431.53

Models	Model-2		Model-5		Model-8	
Variables	Coefficients	SE.	Coefficients	SE.	Coefficients	SE.
RGFCI	0.137***	0.010 [0.000]	0.138**	0.010 [0.000]	0.156***	0.010 [0.000]
EL	0.502***	0.034 [0.000]	0.502***	0.033 [0.000]	0.488***	0.036 [0.000]
TFP	0.726***	0.033 [0.000]	0.726***	0.033 [0.000]	0.676***	0.032 [0.000]
PREC^{+}	-0.003**	0.001 [0.030]	-0.003**	0.001 [0.030]	-0.605**	0.262 [0.021]
PREC^{-}	0.004	0.003 [0.308]	0.004	0.003 [0.308]	0.699**	0.48 [0.445]
ECM	-0.691***	0.073 [0.000]	-0.691***	0.073 [0.000]	-0.732***	0.081 [0.000]
C	0.797**	0.312 [0.023]	0.797**	0.312 [0.023]	1.213***	0.387 0.002]
Chi^2 LL	0.92 [0.969]	-412.45	0.92 [0.969]	-412..44	1.11 [0.954]	-416..88
Models	Model-3		Model-6		Model-9	
Variables	Coefficients	SE.	Coefficients	SE.	Coefficients	SE.
RGFCI	0.141***	0.010 [0.000]	0.141***	0.010 [0.000]	0.147***	0.009 [0.000]
EL	0.512***	0.036 [0.000]	0.513***	0.035 [0.000]	0.500***	0.033 [0.000]
TFP	0.729***	0.034 [0.000]	0.729***	0.034 [0.000]	0.678***	0.028 [0.000]
TEMP^{+}	-0.126**	0.062 [0.020]	-0.126**	0.062 [0.020]	-16.564***	4.607 [0.000]
PREC^{+}	-0.009**	0.004 [0.011]	-0.009**	0.004 [0.011]	-0.330**	0.193 [0.021]
ECM	-0.069***	0.081 [0.000]	-0.069***	0.081 [0.000]	-0.716***	0.081 [0.000]
C	0.993***	0.358 [0.000]	0.993***	0.358 [0.000]	1.037**	0.402 [0.010]
Chi^2 LL	1.98 [0.851]	-425.21	1.98 [0.851]	-425.21	1.20 [0.945]	-422.69

Table 7 indicates that the negative effects of climate change (in terms of both temperature and precipitation) on economic growth even if long term relationships between in the defined models' variables are not linear continues to be valid. In this context, when the Panel NL-ARDL findings in Table 7 are analyzed, it is observed that the symmetrical coefficients of the RGFCI, EL, and TFP variables, which are the main determinants of economic growth, are determined to be positive and statistically significant at 1% level, as expected. (Regarding the statistical interpretation of these results and their effects on economic growth, the relevant sections in which the Panel TSLS findings in Table 5 are evaluated can be seen).

On the other hand, it is noticed that the asymmetric coefficients of the PREC+/ TEMP+ and TEMP–/ PREC– variables calculated negatively in all of the defined models' variables are statistically significant and insignificant, at the level of 1% to 5%, respectively (Table 7). These results show that the positive changes in the climate regime (asymmetric increases in the standard deviations and moving averages of annual average temperature values/annual average precipitation values) have negative and statistically significant effects on economic growth. When Table 7 is analyzed in terms of the magnitude of the effects of positive changes in the climate regime on economic growth, it is noticed that the effects of temperature and precipitation variables on economic growth ranged from approximately -16.56 to -0.126 and from -0.605 to -0.003, respectively. That is, the increase in temperature and precipitation shows that the economic growth of WTE-20 countries decreased by approximately -16.56 and -0.126 and -0.605 and -0.003, respectively. Conversely, the results reveal that the negative changes in the climate regime in terms of the temperature and precipitation dimensions (annual average temperature values/annual average precipitation values asymmetrically decrease in the standard deviations and moving averages) do not affect the economic growth.

6. Conclusion

This study examines the anticipated contractionary effects of climate change on economic growth in the WTE-20 countries over the period from 1990 to 2016. In this context, along with the traditional determinants of the production level such as physical-human capital accumulation and technological development, the models established by extending the CDPF to include climate change were estimated within the scope of the new-generation panel data analysis that takes into account the CSD. As changes in the climate regime, consisting of annual average temperature values (TEMP) and annual average precipitation values (PREC), were represented with six different climatic indicators in the study, namely TEMPSD-1, PRECSD-1, TEMPSD-2, PRECSD-2, TEMPMA, and PRECMA, nine different variations of the three basic models defined in equations were estimated by the above sequence. This paper illustrates that climate change data (TEMPSD-1, TEMPSD-2, PRECSD-1, PRECSD-2, TEMPMA, and PRECMA) in the WTE-20 countries have shown an upward trend since 1990. In particular, it can be observed that this upward trend is relatively higher in TEMPMA and PRECMA variables calculated as moving averages (see Figure 1). The empirical findings obtained from the study can be summarized as follows.

The Panel TSLS overall indicates that with regards to the nine models defined in the WTE-20 countries, it is observed that the coefficients, calculated for all the independent variables in the models, are of similar sizes and significance levels. The results suggest that economic growth performances (while other long-term determinant factors of economic growth are constant) of the WTE-20 countries during the studied period depend mostly on human capital accumulation, technological development level, and physical capital accumulation, respectively. On the other hand, the changes experienced in the climate regime of the WTE-20 countries, that is, increases in the standard deviations and moving averages of annual average temperature values/annual average precipitation values, affect the economic growth negatively and in a statistically significant way. These results demonstrate that climate change in terms of both temperature and precipitation (regardless of the measurement method and indicator representation) has had, consistent with the expectations, contractionary effects on economic growth in the WTE-20 countries during the study period.

The study also examined the robustness of the results, using linear and nonlinear panel datasets, for the period of 1990-2016. Panel L- ARDL results showed that TEMPSD variables affect economic growth negatively between -0.247 and -0.267 units. In other words, a one-unit increase in annual average temperature values causes a decrease in economic growth between -0.267 and -0.247 units. PRECSD variables, on the other hand, affect economic growth negatively between -0.003 and -0.004 units. To be more specific, a one-unit increase in annual average precipitation values results in a decline in economic growth approximately between -0.003 and -0.004 units. The TEMPMA variable also negatively affects economic growth between -2.276 and -1.258 units. It is observed that PRECMA has a negative effect on economic growth between -0.596 and -0.361 units. That is, Panel TSLS and L-ARDL findings support each other in the estimation of the defined models. The obtained results show that the linear increase in the WTE-20 group in the level of physical-human capital accumulation and technological development affects economic growth positively/statistically significantly. In contrast, linear changes in the climate regime reveal that it affects economic growth negatively/statistically significantly. Panel NL-ARDL findings indicate that the effects of climate change led to a decrease in the economic growth of countries in the WTE-20 group for the study period by approximately -16.56 to -0.126 and -0.605 -0.003 units, respectively.

There are uncertainties regarding the effects of climate change on economic growth in terms of regions or severity degrees. Therefore, understanding the effects of climate change on the global economy is important both to reduce the effects of climate change and to develop strategies about this issue. As it is considered that the results obtained from this study can reflect the world average; negative effects of climate change on economic growth can be mentioned. It is thought that climate change adaptation policies are important to reduce the negative effects of climate change on economic growth. IPCC (2007) defines adaptation to climate change as the process of strengthening, developing, and implementing strategies to combat the effects of climate events (risks), gain benefits, and manage impacts. Based on international research and cooperation, led by WTE-20 countries, the realization of these policies can contribute to achieving more effective results. It can be said that it is important for countries to develop policies according to sectors and sub-sectors within the framework of climate change adaptation policies. Thus, it will be possible to understand the impact of climate change on economic growth and to develop more comprehensive measures. Also, considering the effect of greenhouse gas on the increase in temperature values, it is thought that it is important for countries to establish policies to develop renewable energy sources. The limitation of this study is taking into account only temperature and precipitation values, which are the basic climate regime variables in the models. Including other variables that explain the change in climate in models may help reveal the impact of climate change on economic growth more comprehensively. Therefore, more descriptive results can be achieved in future studies by including more climate variables in the model. Future studies may investigate different countries if a sufficient length of data is available. Also, if possible, it may be recommended to group countries by continents and analyze panel data methods. In this way, it can be determined in which continents climate change has more negative effects currently.

References

Abidoye, B.O. and Odusola, A.F., 2015. Climate Change and Economic Growth in Africa: An Econometric Analysis. *Journal of African Economies*, 24(2), pp.277-301.

Akram, N., 2012. Is Climate Change Hindering Economic Growth of Asian Economies?. *Asia- Pacific Development Journal,* 19(2), pp.1-18.

Alagidede, P., Adu, G., and Frimpong, P. B., 2016. The Effect of Climate Change on Economic Growth: Evidence from Sub-Saharan Africa. *Environmental Economics and Policy Studies,* 18(3), pp. 417-436.

Allison, E.H., Perry, A.L., Badjeck, M.C., Adger, W.N., Brown, K., Conway, D., Halls, A.S., Pilling, G.M., Reynolds, J.D., Andrew, L.D. and Dulvy, N.K., 2009. Vulnerability of National Economies to The Impacts of Climate Change on Fisheries. *Fish And Fisheries*, 10, pp.173-196.

Baltagi, B.H., 2008. *Econometric Analysis of Panel Data*, Fourth Edition, West Sussex: John Wiley & Sons.

Barro R.J., 1991. Economic Growth in A Cross Section of Countries. *The Quarterly Journal of Economics*, 106(2), pp. 407–43.

Bosello, F., Eboli, F. and Pierfederici, R., 2012. Assessing The Economic Impacts of Climate Change. *Review of Environment Energy and Economics*, pp. 1-9.

Breitung, J., 2005. A parametric approach to the estimation of cointegration vectors in panel data. *Econometric Reviews*, 24(2), pp. 151-173.

Breuer, J.B., Mcnown, R. and Wallace, M., 2002. Series-Specific Unit Root Tests with Panel Data. *Oxford Bulletin of Economics and Statistics*, 64(5), pp. 527-546.

Colacito, R., B. Hoﬀmann and Phan, T., 2019. Temperature and Growth: A Panel Analysis of the United States. *Journal of Money, Credit and Banking*, 51, pp. 313-368.

Dell, M., Jones, B.F. and Olken, B.A., 2012. Temperature Shocks and Economic Growth: Evidence from the Last Half Century. *American Economic Journal: Macroeconomics*, 4(3), pp. 66-95.

Dellink, R. *et al*., 2014. Consequences of Climate Change Damages for Economic Growth. OECD Economics Department Working Papers, No. 1135. [online] Available at: <http://dx.doi.org/10.1787/5jz2bxb8kmf3-e> [Accessed on July 2017].

Du, D., Zhao, X. and Huang, R., 2017. The Impact of Climate Change on Developed Economies. *Economics Letters*, 153, pp. 43-46.

Eboli, F., Parrado, R. and Roson, R., 2010. Cimate Change Feedback on Economic Growth: Explorations with A Dynamic General Equilibrium Model. *Environment and Development Economics*, 15(5), pp. 515-533.

Ekbom, A. and Dahlberg, E., 2008. *Economic Growth, Environment and Climate Change*. [online] Available at: <http://gmv.gu.se/digitalAssets/1466/1466009_economic_growth_env_and_climate_change_sept_19_2008.pdf> [Accessed on July 2017].

Fankhauser S. and Tol, R.J.S., 2005. On Climate Change and Economic Growth. *Resource and Energy Economics,* 27, pp. 1–17.

Guemide, B., 2017. The effects of climate change on the economic growth of ASEAN countries. [online] Available at: <http://web.isanet.org/Web/Conferences/HKU2017-s/Archive/05d22192-b7f5-43cc-af17-6d2e1760b191.pdf> [Accessed on July 2017].

Hadri, K., 2000. Testing for Stationarity in Heterogeneous Panels. *Econometrics Journal*, 3, pp. 148-161.

Hadri, K. and Kurozumi, E., 2012. A Simple Panel Stationarity Test in the Presence of Serial Correlation and A Common Factor. *Economics Letters*, 115, pp. 31-34.

Henseler, M. and Schumacher, I., 2019. The Impact of Weather on Economic Growth and Its Production Factors. *Climatic Change*, 154, pp. 17–433.

Iglesias, A., Garrote, L., Quiroga, S. and Moneo, M., 2009. Impacts of Climate Change in Agriculture in Europe. PESETA-Agriculture study. *European Commission Joint Research Centre Institute for Prospective Technological Studies*. [online] Available at:

<http://www.eurosfaire.prd.fr/7pc/doc/1260198300_climate_change_agriculture_jrc55386.pdf> [Accessed on June 2020]

Im, K.S., Pesaran, M.H. and Shin, Y., 2003. Testing for Unit Roots in Heterogeneous Panels. *Journal of Econometrics*, 115(1), pp. 53-74.

IPCC, 2007. Climate Change 2007: Synthesis Report. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. [online] Available at: <http://www.ipcc.ch/publications_and_data/ar4/syr/en/contents.html.> [Accessed on July 2017].

IPCC, 2014. Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. IPCC, Geneva, Switzerland, 151 pp.

IPCC, 2018. Global Warming of 1.5 ºC (Special Report). [online] Available at: <https://www.ipcc.ch/sr15/. [Accessed on June 2017].

Jackson, T., 2009. *Prosperity Without Growth? The Transition to a Sustainable Economy. Sustainable Development Commission.* [online] Available at: <https://research-repository.st-andrews.ac.uk/bitstream/handle/10023/2163/sdc-2009-pwg.pdf?sequence=1> [Accessed on June 2017].

Kahn, M.E., Mohaddes, K., Ng, N.C., Pesaran, R., Raissi, H. M. and Yang, J., 2019. Long-Term Macroeconomic Effects of Climate Change: A Cross-Country Analysis. IMF Working Paper, Fiscal Affairs Department. Available at: <https://www.imf.org/en/Publications/WP/Issues/2019/10/11/Long-Term-Macroeconomic-Effects-of-Climate-Change-A-Cross-Country-Analysis-48691> [Accessed on June 2020].

Kolev, A., Riess, A.D., Zachmann, G. and Calthrop, E., 2012. Investment and Growth in the Time of Climate Change. Research Report. https://www.econstor.eu/bitstream/10419/90708/1/776716638.pdf

Kouton, J., 2019.. The Asymmetric Linkage between Energy Use and Economic Growth in Selected African Countries: Evidence from A Nonlinear Panel Autoregressive Distributed Lag Model. *Energy Economics*, 83, pp. 475-490.

Lee, J., Nadolnyak, D. and Hartarska, V., 2012. Impact of Climate Change on Agricultural Production in Asian Countries: Evidence from Panel Study. Available at: <https://ageconsearch.umn.edu/record/119808/files/Lee%20CC%20Asia%20SAEA12F.pdf> [Accessed on June 2020].

Letta, M. and Tol, R.S.J. 2019. Weather, Climate and Total Factor Productivity. *Environmental & Resource Economics, Springer; European Association of Environmental and Resource Economists*, 73(1), pp. 283-305.

Levin, A., Lin, C.F. and Chu, C.S.J., 2002. Unit Root Tests in panel data: Asymptotic and Finite-Sample Properties. *Journal of Econometrics*, 108(1), pp. 1-24.

Levine, R. and Renelt, D., 1992. A Sensitivity Analysis of Cross-Country Growth Regressions. *The American Economic Review*, pp. 942–63.

Mendelsohn, R., 2005. Measuring Climate İmpacts With Cross-Sectional Analysis. *Climatic Change 81, pp. 1–7.*

Mendelsohn, R., Dinar, A. and Williams, L., 2006. The Distributional İmpact of Climate Change on Rich and Poor Countries. *Environment and Development Economics,* 11, pp. 159–178.

Menyah, K., Nazlioglu, S. and Wolde-Rufael, Y., 2014. Financial Development, Trade Openness and Economic Growth in African Countries: New İnsights From A Panel Causality Approach. *Economic Modelling*, 37, pp. 386-394.

Moore, F.C. and Diaz, D.B., 2015. Temperature İmpacts On Economic Growth Warrant Stringent Mitigati on Policy. *Nature Climate Change*, 5, pp. 127- 132.

Ogbuabor, J.E. and Egwuchukwu, E.I. 2017. The Impact of Climate Change on the Nigerian Economy. *International Journal of Energy Economics and Policy*, 7(2), pp. 217-223.

Palm, F.C., Smeekes, S. and Urbain, J.P., 2011. Cross-Sectional Dependence Robust Block Bootstrap Panel Unit Root Tests. *Journal of Econometrics*, 163(1), pp. 85-104.

Pesaran, M. Hashem., Shin, Y., and Smith, R.P., (1999). Pooled Mean Group Estimation of Dynamic Heterogeneous Panels. *Journal of the American Statistical Association*, 94(446), pp. 621-634.

Pesaran, M. H., 2007. A Simple Panel Unit Root Test in The Presence of Cross-Section Dependence. *Journal of Applied Econometrics*, 22(2), pp. 265-312.

Pesaran, M. H., Ullah, A. and Yamagata, T., 2008. A Bias-Adjusted LM Test of Error Cross-Section Independence. *The Econometrics Journal*, 11(1), pp. 105-127.

Pesaran, M. H., Smith, L. V. and Yamagata, T., 2013. Panel Unit Root Tests in the Presence of A Multifactor Error Structure. *Journal of Econometrics*, 175(2), pp. 94-115.

Rodrik, D., 2012. Why We Learn Nothing from Regressing Economic Growth on Policies. *Seoul Journal of Economics*, 25, pp. 137–151.

Sala-i-Martin, X.X., 1997. I Just Ran Two Million Regressions. *The American Economic Review*, pp. 178–83.

Salisu, A.A. and Isah, K.O., 2017. Revisiting the Oil Price and Stock Market Nexus: A Nonlinear Panel ARDL *Approach. Economic Modelling*, 66, pp. 258–271.

Sequeira, T.N., Santos, M.S. and Magalhães, M., 2018. Climate Change and Economic Growth: A Heterogeneous Panel Data Approach. *Environmental Science and Pollution Research*, 25, pp. 22725–22735

Seo, N., Mendelsohn, R. and Munasinghe, M., 2005. Climate Change and Agriculture in Sri Lanka: A Ricardian Valuation. *Environment and Development Economics*, 10, pp. 581–596.

Shin Y., Yu, B. and Greenwood-Nimmo, M., 2014. *Modelling Asymmetric Cointegration and Dynamic Multipliers in a Nonlinear ARDL Framework*. Sickles R., Horrace W. (Eds), Festschrift in Honor of Peter Schmidt. Springer, New York, NY, 281-314.

Solow, R.M., 1956. A Contribution to The Theory of Economic Growth. T*he Quarterly Journal of Economic*s, 70(1), pp. 65-94.

Steiger, R., Scott, D., Abegg, B., Pons, M. and Aall, C. 2019. A Critical Review of Climate Change Risk for Ski Tourism. Current Issues in Tourism. Vol. 22, No. 11, pp. 1343–1379.

Stern, N., 2006. What is the Economics of Climate Change?. *World Economics*, 7(2), pp.1–10.

Taher, H. 2019. Climate Change and Economic Growth in Lebanon. *International Journal of Energy Economics and Policy*, 9(5), pp. 20-24.

Tarı, R., 2010. *Ekonometri*, 6. Baskı, Kocaeli: Umuttepe Yayınları.

Tatoğlu, F. Y., 2013. *İleri Panel Veri Analizi-Stata Uygulamalı*, 2. Baskı, İstanbul: Beta Yayınları

Taylor, M.P. and Sarno, L., 1998. The Behavior of Real Exchange Rates during The Post-Bretton Woods Period. *Journal of International Economics*, 46(2), pp. 281-312.

Temple, J., 2000. Growth Regressions and What the Textbooks Don't Tell You. Bulletin of Economic Research, 52, pp. 181–205.

Tol, R.S.J., 2018. The Economic Impacts of Climate Change. *Review of Environmental Economics and Policy*, 12(1), pp. 4- 25.

Tullo, E., Finzi, A. and Guarino, M. 2019. Review: Environmental impact of livestock farming and Precision Livestock Farming as a mitigation strategy. *Science of The Total Environment,* 650(2), pp. 2751-2760.

UNFCCC, 2020. The Paris Agreement. https://unfccc.int/process-and-meetings/the-paris-agreement/the-paris-agreement. [Accessed on June 2020].

Victor, P.A., 2012. Growth, Degrowth and Climate Change: A Scenario Analysis. Ecological Economics, Ecological Economics 84, pp. 206–212.

World Bank, 2010. Indonesia: Climate Change (Washington, DC: The World Bank, (Available at: http://go.worldbank.org/HQQFW5MV70.

World Bank, 2020. http://datatopics.worldbank.org/world-development-indicators/themes/economy.html. [Accessed on June 2020].