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LONG-TERM MACROECONOMIC EFFECTS OF CLIMATE CHANGE: EVIDENCE FROM THE MENA REGION

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SUSTAINABLE DEVELOPMENT GOALS
AND EXTERNAL SHOCKS IN THE MENA REGION:

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Long-term Macroeconomic Effects of Climate Change: Evidence from the MENA region

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Abstract

This paper focuses on the effect occurring between economic growth and climate change in the Middle East and North Africa (MENA) region. To quantify climate change, we use temperature and precipitation deviations from their historical trends. Several model specifications have been estimated in order to supplement existing attempts to integrate climate change in economic modelling. It has been found that the climate change characterized by temperature and precipitation are impeding to growth.

Keywords: Climate change, economic growth, adaptation, MENA countries
JEL code: C33, O40, O44, Q54

1. Introduction

The MENA region is becoming one of the most heavily affected regions by extreme weather patterns, according to Sieghart et al. (2018). Excessive global temperatures would cause these fewer and more irregular precipitations, changing rainfall patterns, a continued rise in the sea levels, and changes in the water supply. This is all going to happen in a region that already experiences desertification, frequent drought, and water

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shortages. Global warming in the MENA region is bound to influence water supplies, sea levels, biodiversity, public health, food security, land use and urban development, and tourism. Each of these threats exhibits unprecedented challenges to macroeconomic variables such as economic growth and governance which calls for significant initiatives to minimize their adverse and dangerous effects. It will cause hot temperatures to expand over more land for extended periods, rendering some regions inhabitable and limiting cultivated agricultural areas. Cities will feel an excessive heat effect on the mainland, and most of the capital cities in the Middle East and North Africa could confront four months of scorching days every year. Increasing temperatures will place incredible pressure on crops and already scarce water resources (Alboghdady and El-Hendawy, 2016; Ali, 2016; Gilmont, 2015; Nazemi et al., 2020), potentially increasing migration (Balsari et al., 2020; Black et al., 2011; Burrows and Kinney, 2016; Waha et al., 2017) and conflict risk (Scheffran and Brauch, 2014; Sofuoğlu and Ay, 2020; Woertz, 2014).

The MENA region is the most complex regions of the world. In terms of economics, the annual gross domestic product (GDP) per capita ranged from just US$ 1400 in Yemen to more than US$ 20,000 in the Arab Gulf States in 2013 (World Bank 2016). The oil-rich Arab countries of Qatar, Kuwait, and the United Arab Emirates ranked 3, 19, and 24 in Income per capita on the scale of 195 countries in 2013, whereas Morocco, Egypt, and Yemen listed 129, 132, and 155 on the same ranking (World Bank 2016). As a result, adaptation and sensitivity to climate risks vary enormously across the region, especially between the Gulf States and the other MENA countries. In the context of the Paris Agreement, the United Nations Climate Change Framework Convention (UNFCCC), signed by 195 countries, Nationally Defined Contributions (INDCs) reductions in greenhouse gas emissions have been ratified. The INDC details the actions that countries plan to take under the Paris Agreement to become nationally defined contributions (NDCs). Griffiths (2017) defines MENA countries as divided in their response in terms of defining their NDCs. Although the Gulf Cooperation Council (GCC) states have not taken any unconditional commitments to reduce greenhouse gas (GHG) emissions, all North African countries, except for Egypt, there has been at least some sort of unconditional commitment.[1] Likewise, Israel, Jordan, Lebanon, Iraq, Iran, and Yemen have committed to unconditional GHG emission reductions. Therefore, it must be inferred that only a handful of MENA countries are ready to adopt unconditional INDCs. Generally, sufficient awareness of the significance of weather integration in the MENA countries' long-term planning may reduce the risks of wasteful distribution of the expenditure and minimize the risk of duplication and the additional burden. It can also improve coordination across ministries, improve communication and raise public awareness of climate change with other stakeholders. There is no final win-win scenario in many cases, but it is essential to take a closer look at the trade-off between some areas of growth and climate change.

Numerous research has examined the possible economic impacts of climate change (Stocker, 2014; Hsiang, 2016; Cashin et al., 2017; Kahn et al., 2019). Nevertheless, the research studying the climate change-economic growth paradox in MENA countries is scarce. This paper attempts to fill this literature gap by investigating the macroeconomic impacts of climate changes in the MENA region. We study the dynamic effects of temperatures and precipitation deviations from their historical trends on economic growth. Understanding the growth impacts of climate change is crucial in defining each country's responsibilities will differ depending on their national circumstances.

The paper proceeds as follows: Section 2 reviews the literature; section 3 describes the dataset and methodology; section 4 reports our empirical results, and section 5 concludes and draws some policy implications.

2. Literature Review

Since the 1980s, research on global warming has demonstrated that the expected changes would have significant impacts and implications for all world regions. Hence, it is recognized that climate change is one of the significant "megatrends" in future scientific research and future studies. This means that it has a long-life cycle of many years and is expected to be much longer, a global phenomenon that will significantly affect virtually

[1] According to the establishment of the Gulf Cooperation Council (GCC) in May 1981 includes the following countries: Bahrain, Kuwait, Oman, Qatar, Saudi Arabia and United Arab States.

all economic sectors, individuals and institutions. With engagement with other mega-trends and shifts, such as changing demographics, migration, and rapid urbanization, climate change is predicted to raise severe threats to Middle East and North Africa (MENA) countries (Al-Saidi et al., 2020; Sofuoğlu and Ay, 2020).

Characterized by a fragile desert environment and already suffering from aridity, recurrent drought, and water scarcity, the MENA Region is vulnerable to possible impacts of climate change from higher average temperatures, to lower precipitation, and rising sea levels (Tolba and Saab, 2009; Stocker, 2014). Several studies show significant future heatwave beyond human survivor in various countries of the MENA region manifesting significant annual average warming trends ranging from 0.65°C to 1.03°C per decade (AlSarmi and Washington, 2011; Pal and Eltahir, 2016). While the maximum average temperatures increase is between 3°C and 5°C by the middle of the 21st century and almost 5°C to 7°C by the end of the 21st century. The temperature rise will probably be accompanied by a decrease of over 20% in precipitation (Lange, 2019; Lelieveld et al., 2016; Sieghart et al., 2018; Waha et al., 2017).

The MENA region is becoming one of the greatest heavily affected by extreme weather patterns, that anticipates a loss of its GDP by about 0.4 to 1.3 percent which could ascent to 14% if no adaptation and mitigation measures are embraced. All the previous illustrates the need to introduce mitigation measures to limit greenhouse gases (GHG) emissions, primarily from fossil fuels' combustion, to maintain global average temperatures far below the 2°C pre-industrial level (Babiker et al., 2011; Alshehry and Belloumi, 2015). Moreover, adaptive measures and capacity to cope with climate change is facilitated by economic growth (Barr et al., 2010; Bowen et al., 2012).

There is an increasing body of literature studying the effects of climate change on a wide range of economic aspects. These economic outcomes ranges from credit risk (Capasso et al., 2020), agricultural risk and land use (Lu et al., 2020), financial stability and monetary policy (Nasir et al., 2019; Oguntuase, 2020; Sun et al., 2020), to future social economics (Liu and Chen, 2021). The effects of climate change on sectors such as agriculture, animal farming, and tourism, which have a share in economic growth, is 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 several studies, the effects of climate change on economic growth are discussed globally or regionally (Fankhauser and Tol, 2005; Mendelsohn, 2007; Mendelsohn et al., 2006; Bosello et al., 2012).

More specifically, Kahn et al. (2019) examine 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 found that the real output growth per capita is adversely affected by permanent changes in temperature above or below its historical norm while precipitation causes no statistically significant effect. Henseler and Schumacher (2019) investigate the impact of weather on countries' GDP and their main components of production, namely total factor productivity, capital stock, and employment. Their study included 101 country-wide series form 1961 to 2010. The evidence from their study indicates that climate change has a statistically significant negative effect on economic growth. Furthermore, their result show that poorer countries are more vulnerable to higher temperature levels as compared to rich countries. Kadanali and Yalcinkaya (2020) analyze 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 of the world, over the period from 1990 to 2016. The evidence from this study indicates that climate change has negative and statistically significant effects on economic growth. Du et al. (2017) investigate the relationship between temperature and growth within the United States and the European Union. They find that above the optimal temperature, projected rise in temperature have a significant negative impact on the economic growth.

Hoang and Huynh (2020) analyse the impact of climate change on economic growth in Vietnam's coastal South-Central region over the period of 2006–2015. The results indicate that, after controlling for the main determinants in the growth model, the climate change with various proxies has a significant negative impact on provinces' economic growth in the region. Local institutions not only increase economic growth, but also reduce the negative impact of climate change on economic growth as well. Akram (2012) study the effects of climate change on economic growth for selected Asian countries in the period of 1972-2009. He developed a growth model with the inclusion of temperature and precipitation as climate change agents in the production function. To predict the model, he used a fixed-effects model (FEM) and seemingly unrelated regression (SUR), to reach the conclusion that increases in temperature, precipitation, and population negatively affect economic growth. Likewise, Abidoye and Odusola (2015) examined the empirical link between economic growth and climate change in Africa. They proved that climate change has a negative impact on economic growth by using annual data for 34 countries from 1961 to 2009. The authors concluded that an increase of 1°C in temperature decreased GDP growth by 0.67 points.

Moreover, Alagidede et al. (2016) examine the impact of climate change on sustainable growth for Sub-Saharan Africa country panels using panel cointegration modelling techniques. Ogbuabor and Egwuchukwu (2017) analyse 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. Taher (2019) has examined the relationship between climate change and economic growth in Lebanon. The author deployed 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.

In sum the literature assessing the impact of climate change on economic growth shows, thus far, a negative relation regardless it is in the short or long run (Sequeira et al., 2018 ; and Rezai et al. 2018), between poor or rich countries (Dell et al. 2012; and Tol, 2018), exploiting panel (Baarsch, et al., 2020) or time series (Copiello and Grillenzoni, 2020) data, and the employed estimation technique. However, related research is especially crucial for countries and regions with environmental stresses that mainly rely on natural resources and environment to survive and move toward a sustainable economic development, and the MENA region is a typical example (UNEP, 2020). Our paper stems from examining the literature which revealed that studies covering the MENA region are scant. Consequently, this paper investigates the extensive impacts of climate change risks on economic growth in both short- and long-run in the MENA region. Where we attempt to answer the central question: How do climate change affect macroeconomic aspects in the MENA region?

3. Data and Methodology

3.1. Data

We estimate a stochastic growth model for a selected group of MENA countries where GDP growth rate is a function of country-specific climate variables and a set of macroeconomic indicators. Our panel includes annual data for twenty MENA countries over the period 1980-2017. Climate variables, in our dataset, are terrestrial air temperature (°C) and precipitation (mm) obtained from Matsuura and Willmott (2018), which contains 0.5 degrees gridded monthly time series. Following Kahn et al. (2019), we construct population-weighted climate series, using the 2010 gridded population density obtained from CIESIN (2016), and incorporate in our empirical estimation deviations from historical norms. Our macroeconomic indicators, which we collected from the International Financial Statistics (IFS) and World Bank Development Indicators (WDI) databases, include gross fixed capital formation (%GDP), inflation rate, government expenditures (%GDP), credit to private sector (%GDP) and foreign direct investment (%GDP). To proxy for institutional settings, we use *ploty2* index. Table 1 presents the summary statistics of our dataset.

Before exploring the long-run relationship between climate change and economic growth, we start by exploring the data on climate. Figure 1 shows MENA region temperature anomalies. The deviations of temperature from their historical norms over the past 38 years (1980-2017) shows that there is an increasing trend which means climate change is emerging over MENA region. The temperature anomalies range from -1.71 °C to 1.38°C. The positive values start from year 1998 and continue to grow. This time series plot endorses that MENA region witnessed the world warmest temperature in 2016 as

Table 1: Summary statistics

Variable	Description	Mean	Std. Dev.	Min	Max
GDP	GDP growth (annual %)	4.36	6.67	-33.10	54.16
temp	Pop weighted temperature (°C)	21.47	4.69	12.21	29.73
precip	Pop weighted precipitation (mm)	281.18	227.87	3.49	1802.15
inflation	Inflation, GDP deflator (annual %)	7.94	12.46	-26.87	97.43
gov. exp.	Gov. final consumption expenditure (% of GDP)	17.51	6.44	4.58	76.22
invest	Gross fixed capital formation (% of GDP)	24.05	7.76	0.51	93.55
credit	Domestic credit to private sector (% of GDP)	37.18	25.35	0.98	106.34
fdi	Foreign direct investment, net inflows (% of GDP)	2.30	3.78	-13.60	33.57
polty	polty2 index	-5.47	4.23	-10.00	7.00

stated by NASA (2021). Figure 2 depicts the relationship between GDP per capita and temperature (°C). This plot shows an apparent negative relationship. There also two groups of countries facing a downward slope; blue points represent GCC countries and black ones represents Non-GCC countries. However, the GCC countries have higher inverse slope as a result of higher GDP per capita and higher exposure to heat. Figure 3 maps the temperature rise for MENA countries per year over 1980-2017.

Figure 1: Temperature Anomalies - MENA Region

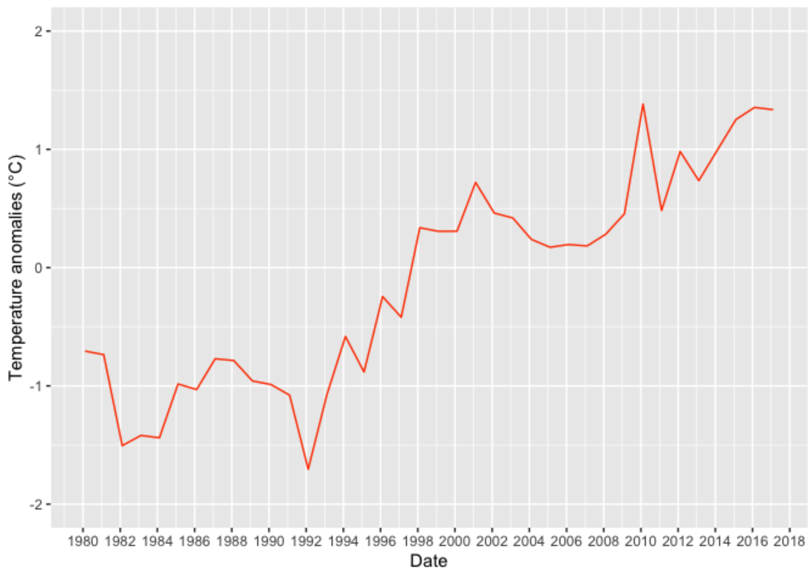
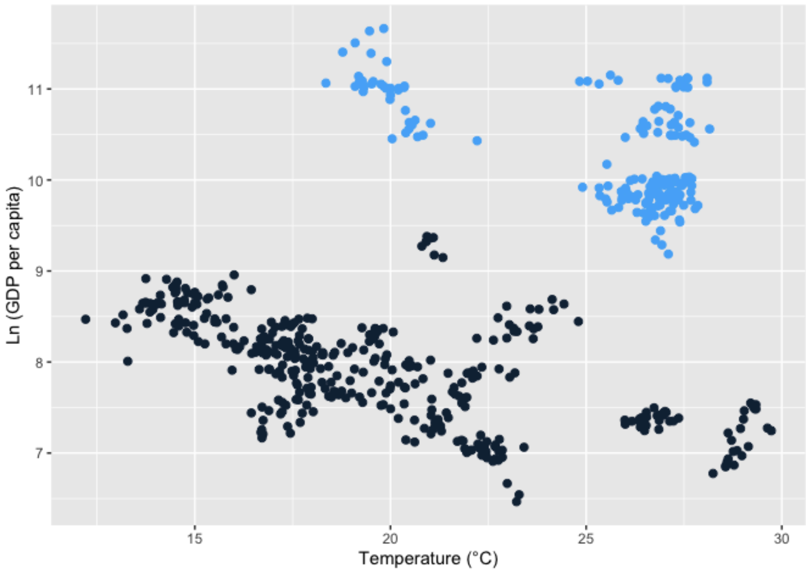
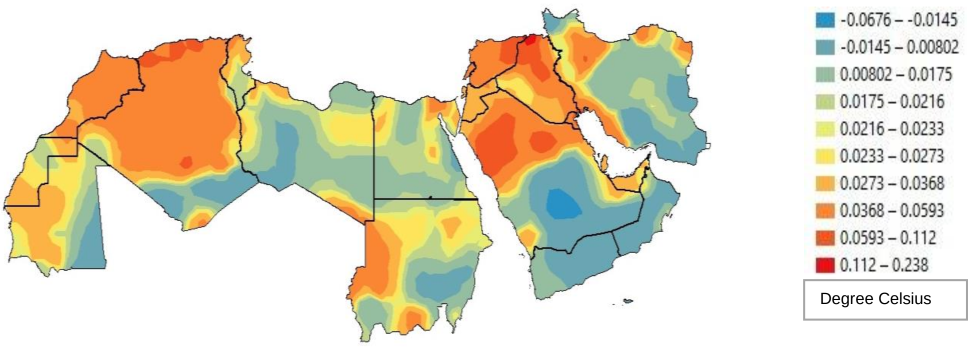


Figure 2: Temperature versus GDP per capita (1980-2017)



Note: Blue dots represent GCC countries and black ones represents Non-GCC countries

Figure 3: MENA countries spatial temperature rise °C per year, 1980-2017



For the empirical strategy, we first report the panel data standard estimators, namely fixed effects (FE) and random effects (RE). However, given that the time dimension T in our panel is relatively larger than the cross-section dimension N, we also apply panel co-integration techniques to estimate our model. First, we test for the integration properties of our cross-section series using three panel unit root tests, namely the Im et al. (2003), Levin et al. (2002) and the LM test proposed by Hadri (2000). We then apply the panel cointegration tests of Pedroni (1999, 2004) and Westerlund (2007) tests. Finally, using the group-mean panel fully modified ordinary least squares (GM-FMOLS) of Pedroni (2001), we estimate the model. GM-FMOLS has several advantages. It accounts for heterogeneity and adjusts for autocorrelation and potential long-term endogeneity problems. Besides, the GM-FMOLS estimator captures cross-section dependencies through common time effects. Therefore, it provides a consistent and efficient estimation even in the presence of endogeneity and serial correlation.

3.2. Fixed Effects and Random Effects

A panel fixed effects model can be presented as follows.

$$y_{it} = \alpha + \beta x_{it} + \mu_i + u_{it} \tag{1}$$

where y_{it}, the dependent variable, is GDP growth rate, in country i and year t, x_{it} a set of regressors, including climate variables and other macroeconomic indicators in our model, μ_i is country-specific time invariant characteristics, and u_{it} is the error term. For estimation purposes, the within-group estimator of the above euqaion can be obtained through regressing demeaned variable which eliminates μ_i as follows.

$$y_{it} - \overline{y}_i = \beta(x_{it} - \overline{x}_i) + u_{it} - \overline{u}_i \tag{2}$$

which could be rewritten as follows.

$$\ddot{y}_{it} = \beta \ddot{x}_{it} + \ddot{u}_{it} \tag{3}$$

where the double doted variables denote the demeaned values. This model can be estimated using OLS, while making a degrees of freedom correction. On the other hand, the random effects model allows for different intercept terms for each country which assumed to arise from a common intercept α, plus a random variable ϵ_i which varies cross-sectionally but is constant over time. The random effects model can be presented as follows.

$$y_{it} = \alpha + \beta x_{it} + \omega_{it}, \quad \omega_{it} = \epsilon_i + v_{it} \tag{4}$$

where ϵ_i measures the random deviation of each country's intercept term from the 'global' intercept term α, and v_{it} is a white-noise error term. This model is usually estimated by the generalised least squares (GLS) procedure which involves subtracting a weighted mean of the y_{it} over time.

3.3. Panel Unit Root tests

Since most unit root tests suffer low power, to examine the integration properties of our panels, we implement several panel unit root tests, namely Levin-Lin Chu (LLC) (Levin et al., 2002), Im-Pesaran-Shin (IPS) (Im et al., 2003), and Hardi LM (Hadri, 2000). Consider the following panel data model with an AR(1) component.

$$x_{it} = \rho_i x_{i,t-1} + \mathbf{d}'_{it}\gamma_i + \epsilon_{it} \tag{5}$$

where $i = 1, \ldots, N$ represents the cross-section units; $t = 1, \ldots, T_i$ is the time index; x_{it} is the series of interest; and ϵ_{it} is an I(0) disturbance term. $\mathbf{d}_{it}$ is the deterministic term, which can be panel-specific means and/or time trend. *LLC* and *IPS* tests examine $H_0 : \rho_i = 1$ for all i against $H_\alpha : \rho \leq 1$. However, they differ in whether the alternative hypothesis holds for at least one panel, some panels, or all panels.

The Hadri (2000) LM test reverses the null hypothesis by testing for stationary panels against the alternative hypothesis of having at least one panel with a unit root. Including a panel-specific time trend, any given x_{it} can be presented as follows.

$$x_{it} = r_{it} + \beta_i t + \epsilon_{it} \tag{6}$$

where r_{it} is a random walk

$$r_{it} = r_{i,t-1} + u_{it} \tag{7}$$

and ϵ_{it} and u_{it} are zero-mean i.i.d. normal errors. If the variance of u_{it} were zero, then r_{it} would collapse to a constant; x_{it} would therefore be trend stationary. Thus, the Hardri LM test tests the hypothesis

$$H_0 : \lambda = \frac{\sigma_u^2}{\sigma_\epsilon^2} = 0 \text{ against } H_\alpha : \lambda > 0$$

3.4. Panel Co-integration Tests

The penal co-integration test of Pedroni (1999, 2004) is a 'residual based test' where stationary residuals would imply the presence of long-run equilibrium. Besides, this test allows for heterogeneous panels and cross section interdependence with different individual effects.

$$y_{it} = \alpha_i + \lambda_{it} + x_{it}\beta_i + \epsilon_{it} \tag{8}$$

$$\epsilon_{it} = \rho_i \epsilon_{it-1} + v_{it} \tag{9}$$

where y_{it} and x_{it} are assumed to be $I(1)$, α_i and λ_{it} are country-specific deterministic components, while ϵ_{it} is an error term that captures any possible deviations from the long-run relationship. Pedroni (1999, 2004) proposes seven residual-based tests under the null of no cointegration. Four of them are based on pooling the residuals for the within group estimation, to test for a null hypothesis of no cointegration given as $H_0 : \rho_i = 0$ for all i against the alternative hypothesis $H_a : \rho_i < 1$ for all i. The other three tests are based on pooling the residuals for the between group estimation, which give group mean panel cointegration statistics as they are based on estimators that average the individually estimated coefficients for each cross-sectional unit.

We also apply Westerlund (2007) test, which is an error correction based cointegration test as follows.

$$\Delta y_{it} = c_i + a_{0i}(y_{i,t-1} - b_i x_{i,t-1}) + \sum_{j=1}^{K_{1i}} a_{1ij}\Delta y_{i,t-j} + \sum_{j=-K_{2i}}^{K_{3i}} a_{2ij}\Delta x_{i,t-j} + u_{it} \tag{10}$$

Westerlund (2007) developed four tests based on 'group mean' and 'pooled panel' estimation. These tests examine the null hypothesis of no cointegration by inferring whether the error-correction term a_{0i} in 10 is equal to zero. Thus, if $a_{0i} = 0$, it implies that y and x are not cointegrated. Two tests are designed to test the alternative hypothesis that the panel is cointegrated as a whole, while the other two test the alternative that at least one unit is cointegrated. According to the alternative hypothesis one can distinguish between group-mean tests and panel tests. The between-group-mean test can be calculated by:

$$G_t = \frac{1}{N}\sum_{i=1}^{N}\frac{\hat{\alpha}_i}{SE(\hat{\alpha}_i)} \tag{11}$$

$$G_a = \frac{1}{N}\sum_{i=1}^{N}\frac{T\hat{\alpha}_i}{\hat{\alpha}_i} \tag{12}$$

$$P_t = \frac{\hat{\alpha}_i}{SE\hat{\alpha}_i} \tag{13}$$

$$P_a = T\hat{\alpha}_i \tag{14}$$

The G_a and G_t test statistics examine the null hypothesis of $H_0 : \rho_i = 0$ for all i against the alternative hypothesis $H_a : \rho_i < 0$ for at least one i. These statistics start from a weighted average of the individually estimated ρ_i and their t-ratios respectively. On the other hand, the P_a and P_t test statistics pool information over all the cross-sectional units to test the null hypothesis of $H_0 : \rho_i = 0$ for all i against the alternative of $H_a : \rho_i < 0$ for all i. The rejection of the null hypothesis is therefore taken as the presence of cointegrating relationship in the panel as a whole.

3.5. Estimating Co-integrated panels

Since our variables are co-integrated, we apply the group-mean panel Fully Modified Ordinary Least Squares (GM-FMOLS) method proposed by Pedroni (2001). The GM-FMOLS estimator allows for the heterogeneity of the panel, adjusts for the effects of autocorrelation of the errors, and adjusts for the potential long-term endogeneity of the regressors. In this estimator, the impact of the cross-section dependence is captured through common time effects. According to Pedroni (2001), the GM-FMOLS estimator is very promising in estimating heterogeneous cointegrated panels. The author shows that the GM-FMOLS provide a consistent and efficient estimation of the cointegrating vector, in particular where non-stationarity, endogeneity and serial correlation problems are suspected. The GM-FMOLS can be presented as follows.

$$z_{it} = \alpha_i + \boldsymbol{\beta}\mathbf{x}_{it} + \mu_{it} \tag{15}$$

and

$$\mathbf{x}_{it} = \mathbf{x}_{it-1} + v_{it} \tag{16}$$

where $z_{it} = \Delta GDP_{it}$, $\mathbf{x}_{it}$ is a vector of the regressors, $\xi_{it} = (\mu_{it}, v_{it})\prime$ is *I(0)* with a long-run asymptotic covariance matrix $\boldsymbol{\Omega}_i$, and z_{it} and $\mathbf{x_{it}}$ are cointegrated for each member of the panel, with cointegrating vector $\boldsymbol{\beta}$. $v_{it} = \mathbf{x}_{it} - \mathbf{x}_{it-1} = \Delta\mathbf{x}_{it}$. Pedroni (2001) makes a non-parametric correction to the OLS estimator to account for potential endogeniety and other econometrics issues. Thus, the GM-FMOLS estimator for β can be computed as follows.

$$\hat{\beta} = N^{-1}(\sum_{i=1}^{N}\sum_{i=1}^{T}(x_{it} - \bar{x}_i)')^{-1} \tag{17}$$

4. Empirical Results

4.1. Baseline Estimation: FE and RE

Table 2 presents the fixed effects and random effects estimations using four different specifications (1 through to 4). Model 1 includes the temperature variable along with investment, inflation rate and government expenditures. Model 2 includes the same set of variables in model 1, but replaces the temperature variable with our measure of precipitation. Model 3 includes the same set of variables in model 1 and 2, while incorporating both climate variables (temperature and precipitation) at the same time. The FE and RE estimation, reported in Table 2 show that higher temperature levels (deviating from historical norms) would be associated with statistically significant and negative impacts on GDP growth rates in the MENA region. However, the estimated coefficient of precipitation seems to be positive in all specifications, but statistically significant only in the random effect estimation of model 2. Other estimated coefficients seem to be in line with growth literature where for example higher investment and FDI levels and better institutional quality (measured by the polty2 index) have positive growth impacts.

Table 2: Fixed Effects and Random Effects Estimations

	FE				RE			
GDP growth	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)
temp	-0.0516**		-0.0547**	-0.00954	-0.145*		-0.122*	-0.0410
	(-2.75)		(-2.79)	(0.14)	(-2.46)		(-2.01)	(-0.68)
invest	0.152***	0.149***	0.150***	0.0746	0.176***	0.170***	0.168***	0.0885*
	(3.79)	(3.73)	(3.76)	(1.82)	(4.66)	(4.45)	(4.40)	(2.28)
inflation	0.133***	0.131***	0.133***	0.0628	0.171***	0.166***	0.165***	0.0891*
	(3.77)	(3.72)	(3.77)	(1.73)	(4.93)	(4.78)	(4.75)	(2.49)
gov. exp.	0.235***	0.237***	0.236***	0.127**	0.207***	0.215***	0.211***	0.104*
	(5.88)	(5.95)	(5.90)	(2.88)	(5.54)	(5.76)	(5.63)	(2.56)
precip.		0.0338	0.0384	0.0178		0.126*	0.0967	0.0597
		(0.48)	(0.54)	(0.26)		(2.10)	(1.57)	(0.99)
credit				0.0646				0.0497
				(1.55)				(1.26)
polty				2.777**				3.051***
				(2.88)				(3.53)
fdi				0.158***				0.163***
				(4.20)				(4.37)
N	760	760	760	760	760	760	760	760

In addition to standard panel estimations reported above, we acknowledge the relatively long time series dimension in our data and therefore employ panel cointegration techniques to investigate the effects of climate change on GDP. Table 3 reports the results for the panel unit root tests of Levin et al. (2002) and Im et al. (2003) for which the null hypothesis is similar: the presence of unit root in individual series in our panel. However, the alternative hypothesis of these tests –except for Hadri (2000) test –differs according to the assumptions each test makes on whether the panel is homogeneous or heterogeneous. Hadri (2000), on the other hand, tests for the null hypothesis of stationary panels. Our panel unit root test results show inconclusive conclusion concerning the integration properties of our individual panel, reflecting the low power of unit root tests. For example, while Hadri (2000) results rejects the null that hypothesis of stationary panels for all variables, Levin et al. (2002) and Im et al. (2003) tests lead to conflicting conclusions for some variables such as GDP growth, investment and inflation. In addition to the panel unit root results presented in Table 3, we implemented the Dickey and Fuller (1981) unit root tests for individual series, which we do not report here for space consideration. The ADF results support the findings from our Hadri (2000) tests for the majority of individual series. We, therefore, continue to test for co-integration.

Table 3: Panel Unit Root Tests

test	GDP	temp	precip.	invest	inflation	gov. exp.	credit	polty	FDI
LLC	-5.9212	1.7994	-0.2093	-2.8367	-7.0523	-2.1217	-0.1427	0.4304	-4.2082
	(0.000)	(0.9640)	(0.4171)	(0.0023)	(0.000)	(0.0169)	(0.4433)	(0.6665)	(0.000)
IPS	-10.5888			-2.3533	-10.7602	-2.8124	0.0359		-7.8226
	(0.000)			(0.0093)	(0.000)	(0.0025)	(0.5143)		(0.000)
Hardi	22.6568	25.9991	1.7488	41.0758	24.3826	36.8178	46.7997	57.8831	31.1265
	(0.000)	(0.000)	(0.0402)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)

Levin-Lin-Chu (LLC) H_0 : panels contain unit roots versus H_a panels are stationary. Im-Pesaran-Shin (IPS) H_0 all panels contain unit roots versus H_a some panels are stationary. Hadri LM H_0 all panels are stationary versus H_a some panels contain unit roots.

With non-stationary pooled time series, the application of the OLS estimator may result in biased and inconsistent estimates (Granger and Newbold, 1974; Engle and Granger, 1987). So, it is important to test for cointegration among our variables of interest. Table 4 reports the test statistics for the Pedroni (1999, 2004) panel co-integration test for GDP growth, temperature, precipitation, investment and government expenditures. Given the large test statistics, we reject the null hypothesis of no co-integration, concluding the presence of cointegrating long-run relationships between climate variables and other macroeconomic indicators in our model. Table 4 also reports the test statistics of Westerlund (2007) panel cointegration test. These results show that we strongly reject the null hypothesis of no cointegration, which implies that it is important to use the panel cointegration techniques to estimate our model.

Table 4: Panel Co-integration tests

	Pedroni		Westerlund	
Statistic	panel	group	Statistics	value
v	-0.1849	.	Gt	-3.565
rho	-4.968	-3.998	Ga	-16.086
t	-11.72	-13.48	Pt	-14.245
adf	-7.393	-7.173	Pa	-15.221

Finally, Table 5 reports our estimations using the GM-FMOLS and GM-DOLS, which average over the individual cross-section. The findings from both estimators confirm our earlier findings using the standard fixed effects and random effects models.

Table 5: FMOLS and DOLS Estimations

		GM-FMOLS				GM-DOLS		
	(5)	(6)	(7)	(8)	(5)	(6)	(7)	(8)
temp	-0.159***		-0.0361***		-0.384*		-0.897**	
	(-3.57)		(-3.62)		(-2.26)		(-2.95)	
invest	0.0616	0.0616	0.134***	0.134***	0.192	0.192	1.794***	1.794***
	(1.49)	(1.49)	(4.12)	(4.12)	(1.08)	(1.08)	(5.55)	(5.55)
inflation	0.351***	0.351***	0.247***	0.247***	-0.0642	-0.0642	-0.447	-0.447
	(6.27)	(6.27)	(5.55)	(5.55)	(-0.21)	(-0.21)	(-1.89)	(-1.89)
gov. exp.	0.364***	0.364***	0.199***	0.199***	0.527***	0.527***	0.977**	0.977**
	(9.79)	(9.79)	(4.83)	(4.83)	(4.16)	(4.16)	(3.16)	(3.16)
precip.		0.159***		-0.0359		0.383*		-0.892**
		(3.57)		(-0.62)		(2.26)		(-2.95)
credit			0.252***	0.252***			1.156**	1.156**
			(4.62)	(4.62)			(2.94)	(2.94)
polty			3.009**	3.009**			-36.70***	-36.70***
			(3.07)	(3.07)			(-6.30)	(-6.30)
fdi			0.287***	0.287***			0.0791	0.0791
			(10.66)	(10.66)			(0.22)	(0.22)

5. Conclusion

Climate change can have adverse impacts on economic growth through many channels, including output, investment, and productivity. Further empirical evidence on the growth impacts of climate change is needed. This evidence is particularly important for policymakers who are responsible for designing policies that aim to mitigate any adverse effects of climate change on the economy. Climate-related issues will also have implications for public budgets and fiscal policy which policymakers in the MENA region should consider, especially in times of low oil prices.

Making use of a panel data of twenty MENA countries over the period 1980 to 2017, were we take into consideration short run and long run effects accounting for cointegration and dealing with the trended climate change variables. Several macroeconomic indicators are also controlled for such as inflation is included in the estimation to represent macroeconomic stability, government consumption expenditure (gov.exp.) as a proxy for aggregate domestic demand, gross fixed capital formation as the percentage of GDP (invest) as a proxy for capital accumulation, and institutional setting along with credit to the private sector (credit) reflecting the increased share of private sector participation in economic activities. Our result show that climate change has long-term negative impacts on economic growth. If temperature diverge by 1°C annually, long-term economic growth will be lower by a range of 0.04 to 0.9 percentage points per year depending on the method of estimation and macroeconomic variables controlled for. The robustness of our results is examined through several model specifications and estimation techniques where the paper supplements existing attempts to integrate climate change in economic modelling.

This paper aims at contributing a comprehensive examination of climate change risks' effects on economic growth in the MENA region. Based on the results, some practical policy and regulatory adjustments to adapt to climate risks and achieve the 2030 sustainable development agenda (SDGs). Developing countries have specific needs for adaptation due to high vulnerabilities. Although many useful steps have been taken in the direction of ensuring adequate adaptation in the MENA countries, much work still remains to fully understand the drivers of adaptation efforts, the importance of future adaptation, and how to mainstream climate into prevailing development policies. Finally, we recommend extending the examination of the relationship between the economic growth and climate change with more desegregated data such as monthly or quarterly series and to account for exogenous shocks such as COVID-19.

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Appendix