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GLOBALIZATION AND ENVIRONMENTAL PROBLEMS IN DEVELOPING COUNTRIES

The impact of age structure on carbon emission in the Middle East: the panel autoregressive distributed lag approach

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Abstract

Rapid evolution in the population age structure of the Middle East countries has major economic, social, and environmental outcomes. Therefore, to fill the gap in the previous literatures, in this study, the effect of age structure on environmental degradation was investigated in the Middle East region. To achieve this goal, a panel data of 10 Middle East countries were examined over the period of 1990 to 2014. Moreover, the carbon dioxide emission per capita was used as an environmental pollution index in this study. According to the stationary property of the variables, small sample size data, and the assumptions of the model, the panel autoregressive distributed lag method of mean group, pooled mean group, and dynamic fixed effect estimators were investigated in this study. The empirical results implied that the pooled mean group model emerged as the most efficient among the three estimators. Also, results revealed that the age structure have a significant relationship with environmental pollution. Children and working age population have a positive elasticity, whereas elderly people have negative elasticity. Furthermore, the results showed that the working age population has the greatest explanatory power on the carbon emissions. Also, the relationship between per capita energy consumption and gross domestic product per capita with air pollution was positive. Overall, the empirical results showed that any attempt to decrease carbon dioxide emissions in the Middle East region should consider the population age structure.

Keywords Age structure · Carbon dioxide emission · Middle East · Panel ARDL

Abbreviations

BHR	Bahrain
CO_2	Carbon dioxide
CPR	Cyprus
DFE	Dynamic fixed effect
EGY	Egypt
GDP	Gross domestic product
GHGs	Greenhouse gases
I(0)	Integrated at level
I(1)	Integrated of order one
IPS	Im, Pesarn, and Shin
IRI	Islamic Republic of Iran
IRQ	Iraq
JOR	Jordan
LBN	Lebanon
LLC	Levin, Lin, and Chu

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MENA	Middle East and North Africa
MG	Mean group
OECD	Organization for Economic Co-operation and Development
Panel ARDL	Panel autoregressive distributed lag
PMG	Pooled mean group
SAU	Saudi Arabia
STIRPAT	Stochastic Impacts by Regression on Population, Affluence, and Technology
TUR	Turkey
UAE	United Arab Emirates
UN	United Nation
WDI	World Bank Development Indicators

Introduction

The size and age structure of the population is changing in the world. Globally, the proportion of children (people under age 15) is declining, while the elderly population (people aged 65 years or over) is rapidly increasing. The elderly population is increasing at a faster rate than the total population and other age groups around the world. For example, the number of older generation is expected to grow by 56% from 901 million to 1402 million between 2015 and 2030 (UN 2015a). Declining fertility rates, war mortality, international labor migration, and refugee crisis reinforce the aging process and inevitable change in the population structure (Omran and Roudi 1993). In addition, healthcare improvements have led to decreasing infant mortality and expanded longevity (Puliafito et al. 2008).

Similarly, in other regions, the population has been growing old in Asia and the Middle East. Moreover, the number and proportion of the old population have significantly increased in the past century (Sheykhi 2018). In 2015, 60% of the total world's population lives in Asia, and more than 50% of the global old population were living in those regions. But, it is expected to see an increase of 73% in the number of oldest-old (people aged 80 years or over) population in Asia within the next 15 years. By 2030, the elderly population is predicted to account for more than 17% of the total populations in Asia (UN 2015b).

Recently, some empirical studies have found that the number and proportion of the elderly population are growing faster in urban settings than in rural areas. One of the immediate causes of this very fast increasing rate in the urban elderly population is the urbanization process especially the migration of population from small rural areas to big cities. The UN has predicted that until 2050, about 64% of the developing countries' population will be urbanized (Shahbaz et al. 2014). However, increasing in the proportion of older individuals is one of the major problems in metropolitan areas which can be unprecedented especially for the past two decades. Unplanned and rapid urban growth has led to higher levels of energy consumptions and environmental damages in most regions (UN 2015c). More than two-thirds of the world's energy consumed is in urban areas. As a result, more than 80% of global greenhouse gas emissions are emitting from metropolitan areas and urban settlements (Un-Habitat 2016). Accordingly, urbanization may lead to higher environmental degradation due to being the major known source of air pollution.

Rapid evolutions in population age structure have major economic, social, and environmental outcomes. Therefore, interest has increased on the study of fluctuations in population age structure. This can impact on environmental degradation and air pollution as the result of greenhouse gas emission (Liddle 2014). The focus of these researches is mainly on the potential effects of population structure especially in working and aged population on greenhouse gas emission. For example, the results from Fan et al. (2006) supported the Malthusian perspectives and showed that the working population had a positive correlation with carbon dioxide (hereafter CO_2) emissions in countries with different income levels. Liddle and Lung (2010) explored that young adults (20–34) had a positive impact on the aggregated CO_2 emission for 17 developing countries, while other cohorts had a negative coefficient. Liddle (2011) discovered that young adults had a positive effect on transport CO_2, whereas the other age structures had a negative elasticity among the OECD (Organization for Economic Co-operation and Development) countries. They believe that the difference between levels of economic activities of different age structure caused these dissimilar effects. Menz and Welsch (2012) found that people aged 15–29 had a positive impact on CO_2 emission in OECD countries, whereas all other age cohorts had a negative effect. They concluded that fully understanding the channels through which age structure effects carbon emissions is somewhat difficult. But, year of birth and childhood experience such as born in times of war or peace seems the main reason of the different effect of age cohort in environmental pollution. Also, Franklin and Ruth (2012) points out that the ratio of people aged over 65 negatively and the ratio of people less than 15 positively correlated with CO_2 emissions in the USA. Their findings showed the direct link between the aging population and CO_2 emission in China. They discussed that the lifestyle of different age structure is the main reason of dissimilar effects of different age group on environmental degradation. Wang et al. (2017) held the view that aging population had a different effect on CO_2 emission in the eastern compared with central and western regions of China. They believe that the different processes of aging population in these regions cause the different results.

According to the literature, most of the age structure studies focused on one or two age structure groups. For instance, Zhu and Peng (2012) solely studied the effect of people aged less than 15 years on environmental damage. Also, Okada (2012), Wang et al. (2017), and Yu et al. (2018) survived the impact of people aged 65 years or over on environmental degradation. In addition, Cole and Neumayer (2004), Martínez-Zarzoso and Maruotti (2011), Franklin and Ruth (2012), and Germani et al. (2014) studied the relationship between two population age structure cohorts and environmental pollution. The findings of the previous research showed that the population and age structure had a significant and different effect on GHG emission in various countries and regions. Therefore, it is necessary to study the effect of all population age structure groups on environmental degradation.

While the average global CO_2 emission per capita was 4.9 tons in 2014, this average for Qatar, Kuwait, Bahrain, United Arab Emirates, and Saudi Arabia carbon emission was 926%, 514%, 477%, 474%, and 397% above the world average emission, respectively. The carbon emission reached to the critical levels in this region (Al-mulali 2012). On the other hand, population has been growing old in Asia and Middle East faster than the world. Therefore, the population structure changed rapidly in the Middle East. According to the literature, the most common variables that were used as the main effective factors on environmental degradation in the past studies included GDP growth, energy consumption, and urbanization. However, to the best of our knowledge, there are few studies that examined the relationship between socioeconomic variables and CO_2 emissions in the Middle East region. Therefore, it is important and necessary to examine the relationship between socioeconomic variables such as population age structure and CO_2 emissions in this region. Table 1 presents the summary information from studies that examined the relationship between these variables in the Middle East and MENA regions. All of these papers listed in Table 1 were published since 2012.

Therefore, it is one of the few studies that focused on the impact of population structure and aging on the environmental pollutions in the Middle East region. In addition, the authors are not aware of any study that has used panel autoregressive distributed lag (ARDL) framework of pooled mean group (PMG), mean group (MG), and dynamic fixed effect (DFE) estimators in the Middle East. Hence, another innovation of this study to the literature is using the panel ARDL according to stationary properties of the variables, assumption of the model, and sample size data. Accordingly, a panel data of 10 Middle East countries over the period from 1990 to 2014 was used in this study. Also, the CO_2 emission was applied as an environmental damage index. Therefore, in this study, the effect of population structure and urbanization on environmental degradation was survived by using the STIRPAT (Stochastic Impacts by Regression on Population, Affluence, and Technology) context in the Middle East.

According to the previous literature, this article tries to fill the gap in the previous studies by answering the main research question, i.e., whether the population age structure has a significantly different effect on environmental pollution? The answer to the main research question from the literature is still mixed across various regions. The result of this study is essential for population planners and policymakers in the Middle East to design acquisitive sustainable development with an improvement in environmental quality.

Data and methodology

Data and variables

All data are obtained from the World Bank Development Indicators (WDI). It also includes five variables, i.e., CO_2 emissions per capita (CO_2), urbanization (U), energy consumption per capita (EC), GDP per capita (GDP), and age structure. Also, most macro-level age structure research typically employed the standard World Bank classification (Liddle 2014). With respect to the standard World Bank classification, the population age structure includes the following: the share of people aged less than 15 years (P_{15}), ratio of population aged 15–64 years (P_{64}), and share of people aged 65 years or over (P_{+65}), which are used in the present study. Hence, another innovation of this study is using all groups of population age structure in the model. In addition, in the present study, the latest available data over the period of 1990 to 2014 is used. The definition of all variables is shown in Table 2.

The 10 selected Middle East countries which were included in the sample of this paper are as follows: Islamic Republic of Iran (IRI), Iraq (IRQ), Saudi Arabia (SAU), Jordan (JOR), Bahrain (BHR), Lebanon (LBN), Cyprus (CPR), United Arab Emirates (UAE), Egypt (EGY), and Turkey (TUR). It should be noted that the World Bank has disseminated only the included data for the above 10 Middle East countries.

Methodology

The main theoretical framework of this study rests upon a highly common and applied context, namely the STIRPAT model. The STIRPAT model was derived from the IPAT model which was proposed by Ehrlich and Holdren (1971). IPAT model, known as I = PAT, studied the impact of socioeconomic variables on the environment and determined by a combination of three components. Three keys of IPAT contain the following: population (P), consumption or per capita affluence (A), and technological level (T) (Chertow 2000; Fischer-Kowalski and Amann 2001; York et al. 2003; Kwon 2005; Hubacek et al. 2007; Liu and Chen 2009; Feng et al. 2009; Hubacek et al. 2011; Brizga et al. 2013). The IPAT model usually was used as an accounting equation (Ehrlich and Holdren 1971) and widely recognized for examining the impact of population on the environment (Harrison and Pearce 2000).

Table 1 Summary of studies that modeled the CO_2 emission in the Middle East and MENA regions

No.	Author	Time period	Region	Number of countries	Variables
1	Al-mulali (2012)	1990–2009	Middle East	12	CO_2, EC, GDP
2	Farhani and Rejeb (2012)	1973–2008	MENA	15	CO_2, EC, GDP
3	Arouri et al. (2012)	1981–2005	MENA	12	CO_2, EC, GDP
4	Farhani (2013)	1975–2008	MENA	12	CO_2, REC, GDP
5	Farhani et al. (2013a, b)	1980–2009	MENA	11	CO_2, EC, U, TO
6	Omri (2013)	1990–2011	MENA	14	CO_2, EC, GDP
7	Ozcan (2013)	1963–2003	Middle East	12	CO_2, EC, GDP
8	Al-mulali et al. (2013)	1980–2009	MENA	20	CO_2, EC, U
9	Farhani et al. (2013a, b)	1990–2009	MENA	9	CO_2, EC, GDP, T
10	Farhani and Shahbaz (2014)	1980–2009	MENA	10	CO_2, GDP, RELC, NRELC
11	Farhani et al. (2014)	1990–2009	MENA	9	CO_2, EC, GDP, T
12	Al-Mulali and Ozturk (2015)	1996–2011	MENA	14	CO_2, EC, U, TO, IO, POL
13	Assadzadeh et al. (2015)	1980–2012	MENA	18	CO_2, GDP, U, GC
14	Fakhri et al. (2015)	1990–2010	MENA	10	CO_2, EC, GDP, U
15	Magazzino (2016)	1971–2006	Middle East	10	CO_2, EC, GDP
16	Abdallh and Abugamos (2017)	1980–2014	MENA	20	CO_2, EI, GDP, U

CO_2, CO_2 emissions; *EC*, energy consumption; *EI*, energy intensity, *GDP*, gross domestic production; *TO*, trade openness; *U*, urbanization; *IO*, industrial output; *POL*, political stability; *T*, trade; *RELC*, consumption of renewable electricity; *NRELC*, consumption of non-renewable electricity

Although the IPAT model is brief, simple, and useful in environmental research, it has pivotal limitations. The main disadvantage of this model is inapplicability in hypothesis testing due to its mathematical nature (York et al. 2003). Furthermore, it assumes a fixed proportionality between the independent variables. In addition, it cannot recognize the relative importance of each factor in the model. Therefore, to overcome the above weaknesses, the STIRPAT model developed by Dietz and Rosa (1994) was utilized in this study. STIRPAT model is a stochastic model which analyzes the stochastic impacts of population, affluence, and technology on environment pressure by regression. The extended STIRPAT model can be expressed by Eq. (1):

$$\mathrm{LnCO}_{2it} = aP^{b}_{it}A^{c}_{it}T^{d}_{it}u_{it} \quad (1)$$

All variables are converted into natural logarithms to reduce the heterogeneity (Farhani et al. 2013a, b). After taking natural logarithms, an empirical linear specification model that captures the interaction between emissions and other variables is gained by Eq. (2).

$$\mathrm{LnCO}_{2it} = a + b(\mathrm{Ln}P_{it}) + c(\mathrm{Ln}A_{it}) + d(\mathrm{Ln}T_{it}) + u_{it} \quad (2)$$

where a is the constant term and u is the idiosyncratic random error term. The b, c, and d are the coefficients which can be obtained from the regression model and showed the elasticity of population, affluence, and technology, respectively. Moreover, the subscript i is the countries and t is the time period. In addition, the STIRPAT model authorizes the researchers to examine the multiple influences of factors on environmental degradation by decomposing the population and technological levels, such as population structure, urbanization, and energy consumption (Yang et al. 2015; Shahbaz et al. 2017). According to this superiority and flexibility of the STIRPAT model, related variables are augmented to the usual

Table 2 Definition of the variables

Variables	Definition	Unit of the measurement
CO_2 emissions per capita (CO_2)	CO_2 emissions divided by the population	Metric tons per capita
Energy consumption per capita (EC)	Energy consumption divided by the population	Per capita of kg of oil equivalent
GDP per capita (PGDP)	GDP divided by the population	PPP (constant 2011 international $)
Urbanization (U)	Urban population growth	Percent
People aged less than 15 years (P_{15})	People aged less than 15 years	Percent
People aged 15–64 years (P_{64})	People aged 15 to 64 years	Percent
People aged 65 years or over (P_{+65})	People aged 65 years or over	Percent

and original model to achieve several research objectives. To analyze the factors affecting CO_2 emissions in the Middle East region, mainly the population factors, this article added the population age structure (young population, working age population, and aging population), urbanization, and energy consumption variables into the STIRPAT model. The estimated model can be shown by Eq. (3):

$$\mathrm{LnCO}_{2it} = \mathrm{LnGDP}_{it} + \mathrm{LnEC}_{it} + \mathrm{Ln}U_{it} + \mathrm{Ln}P_{15it} + \mathrm{Ln}P_{64it} + \mathrm{Ln}P_{+65it} + u_{it} \quad (3)$$

where Ln is the natural logarithm; t and i are the time and country, respectively; CO_2 is the carbon dioxide emission per capita; GDP is the per capita GDP; EC is the energy consumption per capita; P_{15}, P_{64}, and P_{+65} are the three population age structure variables, which refer to the proportion of children and young population (aged 0–14), share of working people aged 15–64 years (aged 15–64), and the share of elderly population (aged 65 and older), respectively. Also, U is to urbanization growth.

The major purpose of this study is to investigate the effect of population age structure on CO_2 emission as the index of environmental pollution in the Middle East region. In order to ensure the robustness of the results, the cross-sectional dependence, a set of panel unit root test, and cointegration test were performed. According to the methodological point of view, prior to applying for panel cointegration tests, the panel unit root test should be performed. Thus, in this section, different panel unit root tests were described before focusing on cointegration tests.

Panel unit root tests

Similar to other panel data research, to analyze the existence of short and long run equilibrium relationship between dependent and independent variables in Eq. (3), the first stage is investigating the order of integration of dependent and independent variables utilizing the panel unit root tests to investigate whether each variable is integrated and have a unit root. In other words, the panel unit root tests are used in order to know the degree of integration for each variable. There are several types of panel unit root test which were used in different studies. But, in this article, the Levin, Lin, and Chu (Levin et al. 2002) and Im, Pesaran, and Shin (Im et al. 2003) tests were used to test the panel unit root.

Testing for panel data method

The panel ARDL is a panel dynamic framework that is newly established and developed by Pesaran and Smith (1995) and Pesaran et al. (1999). This approach is a panel version of the ARDL bounds testing method that is flexible to the assumption and sample size data of the present study. For instance, in the absence of a stationary hypothesis, the panel static methods like pooled OLS, random effect, and fixed effect are unsuitable. Moreover, a dynamic panel method such as the generalized method of moments (GMM) that was proposed by Arellano and Bond (1991) is criticized in the situation that the long panel time series data were estimating. The panel ARDL framework has three estimators that work under the maximum likelihood estimations (Ahmed et al. 2016). The three forms of the panel ARDL are MG, PMG, and DFE. Pesaran and Smith (1995) suggest the use of MG, PMG, and DFE estimation methods with relatively large time series compared with cross sections. In the present study, 25 time series (period of 1990 to 2014) with the 10 cross-section (10 Middle East countries) was used. Therefore, the panel ARDL approach is appropriate to be used in the present study.

In addition to the above points, the panel ARDL method is a robust econometric technique that has several advantages. The panel ARDL framework simultaneously generates both the long and short run coefficients. Also, the panel ARDL approach does not need a homogeneous number of lags for all variables. In addition, this approach can be used even if the independent variables are endogenous. Furthermore, this method is suitable in a condition that variables do not have the same integration level and follows a stationary mixed-order (I(0) and I(1)) in long panel time series data. The panel ARDL is a panel cointegration technique that estimates dynamic panels in which the estimated parameters are heterogeneous across countries. According to the above advantage of the panel ARDL, all of the three estimators (MG, PMG, and DFE) of this approach were used in the present study.

The most flexible specification of panel ARDL is MG which was first introduced by Pesaran and Smith in 1995. In this framework, both the short- and long-term coefficients are permitted to differ across each cross-section (countries in this article). Therefore, in MG estimators, the estimated coefficients are heterogeneous in the long and short runs for each country. The second specification of panel ARDL is PMG estimator proposed by Pesaran et al. (1999). This technique authorizes homogeneous long run coefficients for all countries in this study. But, the short run parameters are heterogeneous across the countries. Meanwhile, the intercepts, slope coefficients, and error variances differ across the countries in the short run. Also, the estimated error correction term must have a negative sign in the short run model. The relationship between age structure and environmental pollution of selected countries in the Middle East region following the panel ARDL(p,q) model equation is showed by Eq. (4):

$$\mathrm{CO}_{2it} = \mu_i + \sum_{j=1}^{p} \gamma_{ij} \mathrm{CO}_{2it-j} + \sum_{j=0}^{q} \delta_{ij} x_{it-j} \quad (4)$$

where $i = 1, 2, \ldots, N$ represents the cross-sectional unit, t represents the time, j represents the number of time lags, p

represents the lag of the dependent variable, and q represents the lag of independent variables. Also, X_{it} represents the vector of independent variables (GDP, EC, U, P_{15}, P_{64}, and P_{+65}).

The last specification is the DFE that has some analogous specification of the PMG. The DFE estimator like the PMG has homogenous coefficient across all countries in the long run. In contrast, the DFE estimator has a homogenous coefficient across all countries in the short run (unlike the PMG estimator). Moreover, the DFE estimator suffers not only from simultaneous equation bias, but also the speed of adjustment coefficient is restricted (Baltagi and Kao 2001). To compare the results of the different panel ARDL estimators, the Hausman specification test was used to measure consistency, efficiency, and to decide if the procedure is appropriate (Hausman 1978). Also, within-cluster error correlation should be considered in the panel data model. But, by increasing the time period, the within-cluster error correlation is decreasing (Cameron and Miller 2015). But, before using panel unit root tests and panel cointegration approach, the cross-sectional dependence in the error terms of panel data model must be checked as the preliminary test. In this paper, the Pesaran residual cross-section dependence (CD) test was used.

Empirical results

The descriptive statistics of all variables for the 10 selected Middle East countries are given in Table 3.

The average CO_2 emissions per capita for all 10 sampled countries in 2014 are about 9.4 metric tons. The top four CO_2 gas-emitting countries are United Arab Emirates, Bahrain, Saudi Arabia, and Iran, whereas Egypt has the minimum CO_2 emissions per capita among the selected countries. The average urbanization is 3.28% with the minimum and maximum recorded at 0.72 and 15.48%, respectively. United Arab Emirates and Lebanon have the highest and lowest urban population. The average GDP per capita for all the 10 sampled countries in 2014 is $27,023.9 US, which confirmed the high-income levels of countries in the Middle East region. In the 10 sampled countries, Iraq and United Arab Emirates have the minimum ($4030.7 US) and maximum ($114,518.8 US) GDP per capita, respectively. The average energy consumption for all the 10 sampled countries in 2014 is 3596 per capita of kilogram of oil equivalent. Bahrain has the largest amount of energy consumption per capita among the selected countries. On the other hand, Egypt has the smallest amount of energy consumption per capita. Among the 10 selected Middle East countries, Jordan's population has the most youth generation followed by Iraq and Iran. Three countries with least young population ratio are the United Arab Emirates, Cyprus, and Bahrain. United Arab Emirates, Bahrain, and Saudi Arabia were among the first less aging population proportion. On the other hand, Cyprus, Lebanon, and Turkey have a much more elderly ratio population.

As mentioned earlier, the Pesaran residual CD test is used before checking the order of integration of all variables. The results of Pesaran residual CD test were reported in Table 4.

Based on the results of Table 4, Pesaran residual CD statistics are insignificant for all variables of model, and the null hypothesis of no cross-section dependence in the error term of the panel model cannot be rejected. These results indicated that all variables do not have evidence for cross-sectional dependence. Therefore, in the next step to select the appropriate econometric model, the order of integration of all variables was checked by the unit root test. Two popular panel unit root tests, namely, LLC and IPS test were performed on all variables. Table 5 presents the results of panel unit root tests for the seven variables (e.g., CO_2, GDP, EC, U, P_{15}, P_{64}, and P_{+65}) in natural logarithms by the two test methods (LLC and IPS), for both at the level and the first difference on individual intercept and individual linear trends.

The second and third columns of Table 5 show the LLC and IPS unit root tests. The last column clearly reports the integration level of each variable. According to Table 5, the results of the LLC and IPS unit root tests are mixed and indicated that all of the variables do not have the same integration level. The null hypothesis of non-stationary can be rejected for the share of people aged less than 15 years (P_{15}), the percent of people aged 15 to 64 years (P_{64}), the percent of people aged 65 years or over (P_{+65}), and proportion of urban population (U) in natural logarithms according to the LLC and IPS unit root tests. Therefore, at 1% level of significance, the P_{15} and P_{64} were stationary at level and they followed an I(0) process. Also, at 10% level of significant, the P_{+65} was stationary at level. According to LLC and IPS tests, the U was stationary at 10% and 1% level of significance, respectively. In contrast, the null hypothesis of the presence of unit root was not rejected for energy consumption per capita (EC) in natural logarithms. Hence, EC was not stationary at level and followed an I(1) process. The results of the LLC test showed that CO_2 emissions per capita (CO_2) and GDP per capita (GDP) were I(0). However, according to IPS test, CO_2 and GDP were not stationary at level and they followed an I(1) process. According to the result of unit root tests, the variables have stationary mixed-order and none of them follows I(2) process, which validates the compatibility of analysis by the dynamic panel ARDL method. Therefore, to see long run relationships between dependent and independent variables, panel ARDL model was used, and Eq. (3) was estimated for the whole sample. The three forms of panel ARDL framework were considered, and the model was estimated with PMG, MG, and DFE procedures. To facilitate the comparison, the results of the three estimators were reported in Table 6.

The estimated error correction is negative and statistically significant in all three ARDL estimators (PMG, MG, and

Table 3 Descriptive statistics of variables for the selected Middle East countries

Variables	CO_2	U	PGDP	EC	P_{15}	P_{64}	P_{+65}
Mean	9.401	3.278	27,023.90	3596.101	31.483	63.894	4.623
Median	4.762	2.689	14,579.56	1639.953	31.372	63.860	3.749
Maximum	35.678	15.480	114,518.8	12,406.71	46.212	85.963	12.559
Country	UAE	UAE	UAE	BHR	JOR	UAE	CPR
Minimum	1.322	0.722	4030.741	528.553	13.340	50.296	0.696
Country	EGY	LBN	IRQ	EGY	UAE	IRQ	UAE
Std. Dev.	8.713	2.181	25,584.51	3731.572	8.173	7.817	2.717
Skewness	1.168	2.757	1.885	1.255	−0.142	0.587	0.966
Kurtosis	2.952	13.018	6.109	2.975	2.186	3.233	3.385
Observations	250	250	250	250	250	250	250
Cross-section	10	10	10	10	10	10	10

DFE). These results indicated that the economic dynamics converge to a long run equilibrium relationship between the explanatory variables and CO_2 emission in selected countries of the Middle East. In other words, considered variables are cointegrated. Also, because of the downward bias in dynamic heterogeneous panels, shifting from MG to PMG and DFE reduces the speed of adjustment (Li et al. 2016). The Hausman test was implemented to determine the selection of these three methods. The results of the pair-wise Hausman test were presented in Table 7.

In the first part of Table 7, the difference between PMG and MG estimators was surveyed by the Hausman test. Also, the result of the difference between PMG and DFE estimators was shown in the second part of Table 7. Based on the first section of Table 7, the Hausman statistic with a distribution is equal to 4.18 with a P value = 0.652 and insignificant. Therefore, the null hypothesis of this test (PMG estimator is preferred than MG estimator) is not rejected. Insignificant Hausman test statistics suggested that the PMG estimator is more superior to MG.

According to the results from the preferred PMG to DFE estimators in the second part of Table 7, the Hausman specification test revealed that PMG estimator is more superior to the DFE. As a result of the Hausman test, PMG regression was

Table 4 Pesaran residual CD test

Variables	Pesaran's CD test	Prob.
$LnCO_2$	−0.669	0.503
LnGDP	1.233	0.217
LnEC	0.839	0.401
LnP_{15}	1.547	0.121
LnP_{64}	1.307	0.191
LnP_{+65}	−1.128	0.259
LnU	0.070	0.943

CD, cross-section dependence

preferred over MG and DFE estimators. Thus, this result implied that the impact of independent variables followed homogenous nature in the long run and followed heterogeneous nature in the short run. In addition, the signs of all long run estimated coefficients in PMG estimator are consistent with the previous literature. The results under PMG estimator in Table 6 indicated that per capita GDP has a positive and significant impact on CO_2 emission. The results show that controlling for the other variables, a 1% rise in GDP is likely to cause a 0.16% increase in CO_2 emission in the selected Middle East countries. The finding indicates that the relationship between energy consumption and CO_2 emissions is positive, and it is statistically significant at 1% level in the long run. The positive energy consumption elasticity suggests that energy consumption increasing is associated with greater carbon dioxide emissions. Controlling for the other variables, a 1% increases in energy consumption is linked with 0.56% growth in CO_2 emissions.

The results from Table 6 revealed that age structure have a significant relationship with environmental pollution. Both the percentage of the people aged less than 15 years (P_{15}) and the people aged 15 to 64 years (P_{64}) are found to positively affect CO_2 emissions in the long run. However, the effect of elderly population (P_{+65}) on emissions was negative. The results showed that in the long run, a 1% increase in young (P_{15}) and working population (P_{64}) will enhance CO_2 emissions by 0.82% and 3.24%, respectively. According to the estimated coefficient, a 1% increase in elderly population (P_{+65}) will reduce the emissions in the long run by 0.70%. Although the signs of population age structure are consistent with the previous literatures, comparing the coefficients of population structure variables indicates that the percent of people aged 15 to 64 years (P_{64}) has the largest effect on emission in the long run. The estimated coefficient of urbanization is not statistically significant. Therefore, urbanization has no significant association with CO_2 emissions in the long run.

Table 5 Panel unit root test results of seven variables in natural logarithms

Unit root test	Levin, Lin, and Chu (LLC)	Im, Pesaran, and Shin (IPS)	Result
Variables at level			
$LnCO_2$	− 1.805** (0.035)	− 1.208 (0.113)	I(0) or non-stationary
LnGDP	− 1.676** (0.046)	0.715 (0.762)	I(0) or non-stationary
LnEC	− 0.596 (0.275)	0.716 (0.763)	Non-stationary
LnP_{15}	− 6.573*** (0.000)	− 3.684*** (0.000)	I(0)
LnP_{64}	− 7.950*** (0.000)	− 6.022*** (0.000)	I(0)
LnP_{+65}	− 3.480* (0.069)	− 1.489* (0.068)	I(0)
LnU	− 1.537* (0.062)	− 3.974*** (0.000)	I(0)
Variables at first difference			
$\Delta(LnCO_2)$	- -	− 13.413*** (0.000)	I(1)
Δ(LnGDP)	- -	− 9.511*** (0.000)	I(1)
Δ(LnEC)	− 11.859*** (0.000)	− 11.410*** (0.000)	I(1)

Probability is shown in the parenthesis

I(0) denotes integrated at level.

I(1) denotes integrated of order one.

******, , Denote significance levels at 1%, 5%, and 10%, respectively

Schwarz-Bayesian information criterion (SIC) has been used for optimal lag length selection

Moreover, the significant and negative error correction term imply that the deviation from the long run equilibrium is corrected by 70.1% each year. Hence, a full convergence process is expected to take less than 1.5 year to reach the stable path of equilibrium. Comparing the coefficients of the independent variables implies that population structure has a larger coefficient than other independent variable in this study. This finding revealed that the most important variable that affects environmental pollution is the structure of age population in each country. But, few studies have focused on the impact of the population structure on the environmental degradation.

The country-specific impact of population age structure on CO_2 emissions was proceeded to show the extent to which the short run findings are different than the long run results. Table 8 highlights the countries in which age structures have a significant impact on CO_2 emissions in the short run.

The results indicated that Bahrain, Cyprus, Saudi Arabia, and Turkey have at least one significant age structure coefficient in the short run. Also, all age structure coefficients of Cyprus are significant at 1% level. The results in Table 8 show that the working population significantly affects CO_2 emissions in all four countries. In addition, all age structure coefficients have negative signs in Cyprus and Turkey. Only the coefficients of age structure in Saudi Arabia have the same sign with long run age structure coefficients.

Discussion

There is well-established literature that examined the impact of different economic factors on CO_2 emissions in the Middle East and MENA regions. However, there is no published article that studies the impact of age structure on the environmental pollutions in the Middle East region. Therefore, to fill the gap in this field, the short and long run effects of population aging, GDP, energy consumption, and urbanization on CO_2 emission were examined using the STIRPAT framework in the 10 selected Middle East countries over the period of 1990 to 2014. In addition, the LLC and IPS panel unit root tests were performed. The results of the stationary test imply that the variables in the model are stationary mixed-order (I(0) and I(1)). Thus, the panel ARDL methodology was used to analyze the short and long run relationship between explanatory variables and per capita CO_2 emission. Furthermore, the Hausman specification test was used to select the efficient and

Table 6 Results from pooled mean group (PMG), mean group (MG), and dynamic fixed effects (DFE) panel ARDL estimators

	PMG		MG		DFE	
	Long run	Short run	Long run	Short run	Long run	Short run
Error correction		− 0.701***		− 1.113***		− 0.512***
		(0.094)		(0.070)		(0.059)
Δ(LnGDP)		0.261		0.191		0.016
		(0.191)		(0.177)		(0.076)
Δ(LnEC)		0.205		− 0.153		0.268***
		(0.167)		(0.249)		(0.090)
Δ(LnP_{15})		1.879		− 29.368		0.038
		(4.735)		(37.238)		(1.140)
Δ(LnP_{64})		− 1.523		− 29.831		− 1.528
		(9.099)		(44.730)		(2.767)
Δ(LnP_{+65})		− 1.525		− 1.373		− 4.141
		(1.230)		(5.628)		(8.590)
Δ(LnU)		− 0.024		− 0.192		0.020
		(0.082)		(0.195)		(0.042)
LnGDP	0.162**		− 0.078		0.197*	
	(0.074)		(0.422)		(0.104)	
LnEC	0.563***		0.774		0.496***	
	(0.053)		(0.498)		(0.109)	
LnP_{15}	0.822***		− 3.886		0.340	
	(0.248)		(6.001)		(0.303)	
LnP_{64}	3.241***		− 2.210		1.199	
	(0.498)		(7.990)		(0.817)	
LnP_{+65}	− 0.700***		− 1.491*		− 0.069	
	(0.156)		(0.840)		(0.175)	
LnU	0.007		0.147		− 0.005	
	(0.017)		(0.178)		(0.044)	
Constant		− 13.568***		36.074		− 5.096***
		(1.794)		(54.568)		(1.951)
Observations	250	250	250	250	250	250

The values in the parentheses are the standard errors (*p* value) of the corresponding coefficient estimates

******, , Significant levels at 1%, 5%, and 10%, respectively

consistent estimator between MG, PMG, and DFE. The results of the Hausman test support the PMG estimator.

The empirical results showed that the age structure had clear effects on CO_2 emission in the long run, and the coefficient of all age population cohort is statistically significant over the reviewed period. In addition, the results illustrated that the age structure variable had a higher contribution to CO_2 emissions than GDP and energy consumption in the Middle East region. This result confirms the findings of previous research that population has a great positive effect on GHGs emission (Fan et al. 2006; Zhu and Peng 2012; Zhang and Tan 2016; Wang et al. 2017; Yu et al. 2018). Therefore,

Table 7 Hausman test result

H_0 and H_1	Chi-square (x^2)	Prob
H_0: PMG estimator is efficient and consistent, but MG is not efficient H_1: PMG estimator is not efficient, but MG is efficient	4.18	0.652
H_0: PMG estimator is efficient and consistent, but DFE is not efficient H_1: PMG estimator is not efficient, but DFE is efficient	0.13	1.000
H_0: DFE estimator is efficient and consistent, but MG is not efficient H_1: DFE estimator is not efficient, but MG is efficient	0.01	1.000

Table 8 Countries with significant impact of age structure in the short run

Age structure	P_{15}	P_{64}	P_{+65}
BHR	− 10.03***	− 30.35***	1.46
	(3.87)	(10.61)	(2.14)
CPR	− 18.10***	− 54.29***	− 9.75***
	(6.42)	(19.72)	(4.46)
SAU	34.12***	40.39**	− 5.63
	(12.57)	(17.08)	(4.79)
TUR	− 4.12	− 19.69*	− 0.63
	(3.32)	(10.34)	(0.83)

The values in the parentheses are the standard errors (*p* value) of the corresponding coefficient estimates

******, , Significant levels at 1%, 5%, and 10%, respectively

the impact of the population age structure cannot be ignored in GHGs emission studies, and age structure should be included in the GHGs control policies. Because various age cohorts have several economic activities and they have different energy consumption which has led to distinct carbon emission. Hence, any attempt to decrease carbon dioxide emissions in the Middle East region should consider the population age structure.

The empirical results indicated that the percentage of people aged 15 to 64 years has a positive correlation with CO_2 emission in the long run. This finding is consistent with the results of Shi (2003), Fan et al. (2006), York (2007), Zhu and Peng (2012), and Yang et al. (2015). In addition, the results showed that the working age population has the greatest explanatory power (+ 3.24) on the carbon emissions, and the elasticity of CO_2 with respect to the ratio of population aged 15–64 years is larger than unity. The working age cohort has increased the environmental pollution directly and indirectly from two main channels. First, the labor force population consumes more energy than children, young, and elderly population, and they emit more GHGs. Second, the working population has more production activity, and they have a larger carbon footprint.

Therefore, changes in the proportion of the working group have led to greater changes in CO_2 emission. Literally, the ratio of labor force matters and all governments in the Middle East countries should take it into account before implementing environmental policies. As an applied policy, encouraging the use of public transportation, electric vehicles, and bicycle among the people aged 15 to 64 years are suggested.

According to the long run estimated parameters, the elderly population has a significant negative impact (− 0.70) on CO_2 emission, and it has a different role in environmental pollution. This result is consistent with the findings of previous studies such as Liddle and Lung (2010), Liddle (2011), Franklin and Ruth (2012), Okada (2012), and Yang et al. (2015), and is inconsistent with Zhang and Tan (2016). This might be due to differences between the lifestyle of the old generation in the Middle East countries compared with the other developed and developing countries. In this region, elderly people usually live with their children, and they have lower economic activities. Also, they do not use a private vehicle and prefer to take public transportation compared with the working age population. In addition, the elderly population has a lower demand for food, water, as well as energy which lead to less CO_2 emission. Besides, the demand for elderly population for transportation has reduced by increasing in age.

The empirical results showed that the proportion of young people have a significant effect on CO_2 emission that are inconsistent with the results of Franklin and Ruth (2012). The estimated elasticity explained that increase in the share of the people aged less than 15 years has led to a rise in CO_2 emission, and 10% increase in young population will enhance CO_2 emissions by 8.2%, holding all other variables constant. This finding is inconsistent with the results of Yang et al. (2015) which indicated that the shrinking young population boosts the discharge of CO_2 emission in Beijing. The young population consumes less energy than other population groups. Moreover, they are less engaged in production activities and hence they have a lower carbon footprint. As mentioned before, most of the previous studies focused on one or two groups of the age structure. They argued that other aging groups have the same energy consumption pattern, and consequently they have the same effect on the environment. Therefore, they removed some population aging groups from their model. But, the results of the present study showed that only children and working age populations have the same (positive) elasticity, whereas elderly people have negative elasticity. Also, the absolute impact of each group is different. For instance, the results showed that the young and working population elasticity is equal to 0.82 and 3.24, respectively. In contrast, the absolute value of the estimated coefficient for the elderly population is about 0.70 in the long run. Although the population age structure groups may have the same effect on environmental degradation, the elasticity of each group is different. Therefore, the people aged less than 15 years should choose as the second goal group in any carbon reduction policies in the Middle East region.

The energy consumption coefficient is positive and statistically significant. This is due to the fact that fossil fuel energy consumption is more than 95% of total energy consumption in the Middle East. This suggests that the governments in the Middle East should decrease the energy, which subsides for correcting the energy price signal and improves the energy consumption. Also, developing a low carbon and green energy technologies such as wind, solar, hydro, and biogas that were used by working group are essential for the selected

Middle Eastern countries. The elasticity of CO_2 with respect to energy consumption is less than unity (+ 0.56). Also, the coefficient of energy consumption is smaller than young, elderly, and working population for the absolute values. The findings illustrated positive correlation between economic growth and CO_2 emission. This finding is consistent with numerous study arguments such as Farhani et al. (2013a, b), Shahbaz et al. (2015, 2013, 2014, 2016), Farhani and Shahbaz (2014), Magazzino (2016), Ahmad et al. (2016), and Yu et al. (2018). Therefore, utilizing new technologies with lower CO_2 emissions, carbon taxation, determining the technical production standard, tax incentive for low carbon products, and improving production technologies are the suggested applied policies. However, it is important that economic development policies aim to reduce CO_2 emissions. The estimated elasticity for the economic growth (+ 0.16) had the smallest value among all significant estimated coefficients in the long run. According to panel ARDL approach findings, the impact of urbanization on carbon emission is not statistically significant. This outcome is consistent with a number of studies conducted by Sadorsky (2014), Asane-Otoo (2015), Xu and Lin (2015), and Rafiq et al. (2016). The results of the present study can add new knowledge to the existing literature by including age structural in the STIRPAT model which is rarely examined by the previous studies and especially in the Middle East region.

Conclusions

This paper investigated the impact of age structure on CO_2 emissions using panel data for the 10 Middle East countries from 1990 to 2014. The STIRPAT model was investigated to study the impact of population structure (people aged less than 15 years (P_{15}), people aged 15–64 years (P_{64}), and people aged 65 years or over (P_{+65})), EC, PGDP, and U on CO_2 emission (CO_2). In terms of econometric methodology, the STIRPAT model was estimated by using the panel ARDL with three forms (contain MG, PMG, and DFE) to deal with stationary mixed-order of the explanatory variables.

Based on the PMG estimator, the working population, children, and elderly population are the most important factors, and age structure is strongly related to environmental damage in the Middle East region. Unlike people aged less than 15 years and people aged 15–64 years, the elderly population had a negative impact on CO_2 emission. In addition, the elasticity of environmental damage with respect to the working population was larger than unity. Therefore, the population structure should be included in environmental pollution models. In addition, these findings indicated that the environmental quality improvement policies should vary at countries with different population structure. Also, energy consumption, GDP per capita, and urbanization were positively affected by CO_2 emissions. Overall, the empirical results of this study showed that any attempt to decrease CO_2 emissions in the Middle East region should consider the population age structure especially working for the age population group. Population in several age cohorts had distinguished effect from other age population groups. Accordingly, the working age population should be selected as the main target group for environmental policymaking in the Middle East.

In this paper, only the CO_2 emission was used as an indicator of environmental degradation. Future researches should investigate the composite index of environmental performance (CIEP) as the index of environmental damage. Also, in future studies, other effective factors such as different kinds of energy resources, renewable, and non-renewable energy should be considered. In the present study, the standard World Bank classification of age structure (0–14, 15–64, and aged over 65) is used for grouping the population. For future research, the impact of other age classifications on carbon emission should also be taken into account. Also, the main limitation of this study is lack of data for some Middle East countries.

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Compliance with ethical standards

Ethical statement The manuscript has not been previously published, is not currently submitted for review to any other journal, and will not be submitted elsewhere before a decision is made by this journal.

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