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The relationship between energy, pollution, economic growth and corruption: A Partial Least Squares Structural Equation Modeling (PLS-SEM) approach

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Abstract

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At the end of 2010, the Middle East and North Africa (MENA) region confronted the Arab Spring that caused political instability and heightened economic risks. In fact, it became necessary to correlate in further research the corruption with energy consumption, economic growth and CO2 emissions. This study used time series data from 1996 – 2012 in the MENA region with the main aim to contribute to empirical literature by using the PLS-SEM approach. Results from the PLS-SEM show evidence of economic growth causing CO2 emissions. Second, energy consumption is positively and significantly related to economic growth and also may increase CO2 emissions. Thirdly, this research supports the view that corruption moderates economic growth and worsens the environmental quality in the MENA region. Finally, the use of the PLS-SEM reduces complexity and allows a better understanding of these relationships.

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1. Introduction

The causality between energy consumption, economic growth and carbon dioxide (CO_2) have increased around the world and have been extensively analyzed over the last years by many researchers (Saidi and Hammami, 2015; Ben et al., 2016; Shahbaz et al., 2016; Zhao et al., 2016). In recent years, combining the corruption issue, political stability and environmental quality has made an attractive field of research (Farooq et al., 2013; Fredriksson and Neumayer, 2015; Zhang et al., 2016; Zhao et al., 2016; Adams et al., 2016). In addition, CO_2 is rapidly increasing in the MENA country compared to other more developed countries. The origin of these changes may be due to the natural variability of climate or human activities. Different empirical studies demonstrated that exist a different way of causality on the long-term and the short-term impact between different indexes. Moreover, most existing research focuses on the interaction between energy and pollution or corruption and economic growth. However, few studies have been made to test these four links in the same framework. This paper is an attempt to fill this area in the case of MENA region.

The MENA region is rich in natural resources and plays a vital role in the global energy system. Since 2011, the MENA region confronted the Arab Spring and political instability. It became urgent to take into account the impact of corruption in further empirical studies. In addition, this topic has attracted the attention of global financial institutions, such as the World Bank and rating agencies in the recent years due to its detrimental impacts on economic growth.

This study aims at investigating the relationships between energy consumption, corruption, environmental quality and economic growth in 16 Middle East and North African (MENA) countries over the period of 16 years (1996 –2012). Our paper adds to the literature on the MENA countries in several meaningful ways. First, none of the previous studies explicitly highlight the role of corruption and fiscal freedom is essential in explaining the unconvincing results of growth and energy consumption on CO_2 emissions in MENA region (Fadel et al.,2013; Farhani et al., 2014; Saidi & Mbarek, 2015; Omri et al., 2015; Abdouli & Hammami, 2016). Second, the use of partial least squares structural equation modeling (PLS-SEM) to establish a relationship between energy consumption, corruption, economic growth and CO_2 emissions. To the best of our knowledge, we perform, for the first time, an application of this relationship with this technique. PLS-PM is suitable for analyzing the economic area. In fact, the popularity of PLS-SEM continues to increase in various disciplines such as statistics (Pagès and Tenenhaus, 2001; Härdle, 2011), accounting (Mourad and Valette-Florence, 2016; Nitzl, 2016), finance (Blanco-Oliver et al., 2016; Ratzmann et al., 2016), strategy (Sarstedt et al. 2014) and marketing (Rezaei, 2015; Chuah et al., 2017). Third, this study analyzes the interaction between four latent variables in the same model. However, most studies use separate models to estimate the causality between indicators. Fourth, prior researchers lack an answer to whether control of corruption and higher fiscal freedom consistently improve the quality of the environment. This study provides a means of quantifying the moderating role of control of corruption and fiscal freedom and would guide policy-makers to adopt new techniques for implementation of environmental regulation in relation to the levels of corruption and economic growth in MENA region.

The rest of the paper is organized as follows. The subsequent section will provide the literature review and develop the research hypotheses. Second, we describe both the methodology and the data used to test our hypotheses in Section 3. Then, Section 4 discusses the empirical results of this study. Ultimately, the conclusions and policy implications are presented in Section 5.

2. Literature review

Energy is considered as the most relevant resources used in the production process and it is used as extensively as capital and labor in the MENA region. All countries continue the current level of production during the recent years. It is the main reason why the scientists argue that energy consumption is responsible for carbon dioxide (CO_2) emission, which is one of the major causes of creating Green House Gas (GHG) in the atmosphere (Alam et al., 2016). Since the 1990s, there has been increasing attention on the impact of the energy consumption on the environment and therefore extensive empirical literature to consult (Koirala et al., 2011; Kaika and Zervas; 2013; Stern, 2014; Ahmad et al., 2016; Sekrafi and Sghaier, 2016; Kempa and Khan, 2017). Table 1 gives an overview of the main studies related to CO_2 emissions, energy consumption, and GDP growth. Rafindadi (2016) shows that a complete significant relationship exists between energy consumption and carbon emission in five West Africa countries between 1980–2010. Bouznit and Pablo-Romero (2016) demonstrate in their results that an increase in electricity use and energy consumption increase CO_2 emissions in Algeria using the autoregressive distributed Lag (ARDL) co-integration technique. Oscan (2016) indicates the positive causality in the long run between economic growth, energy and CO_2 emissions, especially in 5 Middle East countries. Saidi and Hammami (2015) show a positive impact of CO_2 emissions on energy consumption for 58 countries using a dynamic panel data estimated using the Generalized Method of Moments. Alam et al. (2016) use the Autoregressive Distributed Lag (ARDL) to examine the impact of income, energy consumption and pollution growth on CO_2 emissions. Their results show that pollution has increased together with increases in revenue and energy consumption in India, Indonesia, China and Brazil. Miao (2017) indicates that the population scale is the factor in increasing energy consumption and CO_2 emissions and encourages technological innovations for urban China in order to reduce pollution. To further contribute to this debate, it is hypothesized that:

H1. Energy consumption has a positive impact on pollution.

Nevertheless, less attention has been given examination of the linkages between corruption and air pollution and focused on the relationship between per income and pollution. Winbourne (2002) suggests that corruption may contribute to the increase of environmentally damaging policies and damaging practices. Welsch (2004) analyzes the impact of corruption on the environment. Fredriksson et al. (2004) find theoretical and empirical effects of corruption on environmental policy. Cole (2006) uses data for 94 countries from 1987–2000 for two air pollutants, sulfur dioxide (SO_2) and carbon dioxide (CO_2), their results show a positive effect of corruption on pollution. The empirical results of Biswas et al. (2012) indicate that the causality between the shadow economy and the levels of pollution depended on the degree of corruption. Ozturk and Al-Mulali (2015) use a generalized method of moments and two stages least squares. Their findings show that the control of corruption could reduce CO_2 emissions. Zhang et al. (2016) develop a panel data model in order to examine the impact of corruption on CO2 emissions the Asia-Pacific Economic Cooperation (APEC) from 1992–2012. Their empirical results indicate that corruption may worsen the environmental quality.

For another, there was considerable empirical literature that studied the indirect effect of corruption on economic growth. The study of Mauro (1995) demonstrates that corruption may decrease economic growth by reducing investment. Rock and Bonnett (2004) use a time series model which supported that corruption damages growth and reduces investment in most of the developing countries but contributed to the increase in the large East Asian economies. Some studies explain the negative causality between taxation, corruption and firm growth (Fisman and Svensson, 2007). Aparicio et al. (2016) suggest that countries controlling corruption is fundamental to generating entrepreneurship opportunities and have a positive impact on economic growth. Therefore the following hypotheses are set up:

H2. Corruption has a positive impact on pollution.

H3. Corruption has a negative impact on economic growth.

The study of Karl (2004) indicates that high corruption and exceptionally bad governance often characterize countries dependent on oil. Fredriksson et al. (2004) reveals that corruption affects environmental policy. Arezki and Brückner (2011) find a positive correlation between oil rents and corruption for a panel of 30 oil exporting countries from 1992 to 2005. Al-Mulali (2011) showed that the economic situation in the MENA region is influenced by fluctuations in oil price and political instability. Saha and Benali (2016) find that countries that are rich in natural resources are characterized by high corruption, such as MENA region. More specifically, the statistics provided by World Bank (2012) indicate that the MENA region covered approximately 57 percent of the world oil reserves and roughly 41 percent of natural gas resources. Tang and Abosedra (2014) claimed in their results that energy consumption contributes to the political stability in the MENA region. Therefore, we hypothesize that:

H4. Energy has a positive impact on corruption

A considerable empirical study confirms the existence of a correlation between energy and economic growth. Some researchers indicate that economic growth may increase energy consumption (Hamilton 1983; Katircioglu et al., 2015; Lardic and Mignon, 2008), this literature seems to demonstrate that a relation between energy price and economic growth are classified as a negative to a positive effect depending on the level of oil dependency of the country under study and a clear negative impact of the oil price on economic growth for net oil-importing countries (Fizaine and Court, 2016). Chen et al. (2016) use a panel co-integration and vector error correction to estimate the relationships between economic growth and energy, their conclusion approves that energy negatively affects Gross Domestic Product (GDP) for 188 countries over the period of 1993–2010. The empirical results of Hossain (2011) indicate that the trade openness and urbanization of the environment are good for economic growth in the long-run. Saidi and Hammami (2014) apply simultaneous equation models to 58 countries over the period going from 1990–2012. Their results show that energy consumption played an important role in the increase of economic growth. Mutascu (2016) establish a bi-directional relationship between energy consumption and economic growth in the G7 countries during the period of 1970–2012, and suggested that an increase of the GDP causes a rise in energy consumption; therefore, the policy conservation of energy consumption can affect the growth performance. Osman et al. (2016) suggest that the presence of bidirectional causality between economic growth and electricity consumption and indicate that any adoption of conservation policies in energy may have a negative impact on economic growth.

In order to clarify this body of knowledge, we hypothesize that:

H5. Energy consumption has a positive impact on economic growth.

Saidi and Hammami (2014) demonstrate that increasing CO_2 has an adverse effect on economic growth and decreases the GDP in any given country. Ahmed et al. (2016) investigate the long and the short run relationship between carbon emissions and economic growth in India. The empirical analysis shows the existence of causality in inverted U-shaped in the long run between carbon emissions and economic growth. Saboori and al. (2014) use the Fully Modified Ordinary Least Squares co-integration approach in time series data from 1960 to 2008 demonstrating that there is a significant positive long-run bidirectional relationship between CO_2 emissions and economic growth. Ozcan (2013) indicates the presence of a unidirectional causality from economic growth to CO_2 emissions in the long-run for 12 Middle East countries from 1990 to 2008. Adewuyietand Awodumi (2017) ran the simultaneous equation model estimated with three stages least squares to investigate the correlation between biomass energy consumption, economic growth and carbon emissions. Their result shows that a total causality exists between GDP and CO_2 in West Africa from 1980–2010.

H6. Economic growth has a negative impact on CO_2

The conceptual model displayed in Fig.1 summarizes the research hypotheses to be empirically tested.

Table 1

Typical literature related to the linkage between corruption, economic growth, energy and pollution.

Literature	Country and period	Methodology	Causality
Damania et al. (2003)	Mix of developed and developing countries (1982 – 1992)	Random effect regression model	In the long run: COR→ CO_2
Fredriksson et al. (2004)	Twelve OECD countries (1982 – 1996)	Generalized linear square estimation (OLS)	In the long run: COR→ EC
Ang (2007)	France (1960 – 2000)	Johansen cointegration test ; ARDL bound test ; VECM	In the long run: GDP → CO_2 GDP → EC In the short run: EC → GDP
Halicioglu (2009)	Turkey (1960 – 2005)	ARDL bound test	In the long run: EC ↔ CO_2 GDP → CO_2 EC → GDP In the short run: GDP ↔ CO_2 EC → CO_2
Apergis and Payne (2010)	Twenty OECD countries (1985 – 2005)	Pedroni cointegration tests; panel FMOLS; panel VECM	In the short run: GDP → CO_2 EC ↔ GDP EC ↔ CO_2
Arouri et al. (2012)	12 MENA countries (1981 – 2005)	Panel data analysis	In the long run: GDP→ CO_2
Biswas et al. (2012)	More than 100 countries (1999 – 2005	Panel data model	In the long run: GDP→ CO_2 COR→ GDP
Saboori et al (2012)	Malaysia (1980-2009)	Johansen cointegration test; VECM	In the long-run: GDP → CO_2

Table 1 (continued)

Literature	Country and period	Methodology	Causality
Ocal and Aslan (2013)	Turkey (1990 – 2010)	ARDL bonds testing, Toda–Yamamoto procedure.	In the long-run: GDP → EC
Muhammad et al. (2013)	China (1971 – 2011)	ARDL bounds tests, VECM.	In the long-run: EC ↔ GDP
Ozcan (2013)	12 Middle East Countries GCC (1990 – 2008)	Panel data analysis	In the long run: GDP → CO_2 EC → CO_2 In the short run: GDP → EC
Yang and Zhao (2014)	India (1970 – 2008)	Granger causality tests and directed acyclic graphs.	In the long run: EC→CO2 EC→ GDP CO2 ↔GDP
Ozturk and Al-mulali (2015)	Cambodia (1996 – 2012)	Generalized method of moment and two-stage least squares (2SLS)	In the long run: COR→ CO_2
Aparicio et al. (2016)	43 countries (2004–2012)	Panel data model	In the long run: COR→ GDP
Wang et al. (2016)	China (1995 – 2012)	Johansen cointegration test; VECM	. GDP → CO_2
Sekrafi and Sghaier (2016)	MENA Countries (1984 –2012)	Static and dynamic panel data	In the long run: COR→ GDP COR→ CO2 COR→ EC
Kahouli (2017)	6South Mediterranean countries (1995 –2015)	Bound tests for cointegratio n, ARDL approach and VECM method	In the long run: EC ↔GDP In the short run: EC → GDP: except Egypt.
Ahmad and Du (2017)	Iran (1971 –2011)	ARDL approach	In the long run: GDP → CO_2 EC → GDP
Appiah (2018)	Ghana (1965 –2015)	Toda-Yamamoto and Granger causality tests	In the long run: GDP → CO_2 EC → GDP EC → CO_2

Notes: EC→GDP means that the causality runs from energy consumption to growth. GDP→ EC means that the causality runs from growth to energy consumption. GDP→CO2 means that the causality runs from economic growth to pollution. EC↔GDP means that bidirectional causality exists between energy consumption and growth. CO2↔GDP means that bidirectional causality exists between pollution and economic growth. COR↔GDP means that the causality runs from corruption to economic growth. COR→EC means that the causality runs from energy consumption to corruption. COR→CO2 means that the causality runs from corruption to pollution.

3. Methodology

3.1. PLS-SEM

In order to evaluate the empirical relationship between latent variables, this paper uses PLS-SEM. The method was proposed in (Wold, 1982). The estimation method is based on the sequential use of orthogonalization and PLS regression and benefits from some advantages (Tenenhaus et al., 2005; Vinzi et al., 2010; Nitzl, 2016) like the conditions relating to sample size, correlation and normal distribution. This method can handle a small amount of data which improved statistical reliability. PLS-SEM test complex theories with empirical data (Sarstedt et al., 2014). Hair et al. (2012) indicates that an essential characteristic of PLS-SEM is that it provides latent variable scores as specific linear combinations of their manifest variables. Shmueli et al. (2016) show that the success of PLS comes from its ability to estimate the parameter of complex models without many of the distributional and other constraints of traditional econometric models. PLS-SEM has become a common statistical method in many fields of science (Becker et al., 2013; Schubring et al., 2016; Rönkkö et al., 2016; Hair et al., 2017). Path models with latent variables cover measurement models that describe the relationships between latent variables and their observed indicators. The estimated structural model proposed by (Tenenhaus et al., 2004) is defined as follows. In the first procedure, the latent variables were determined by the manifest indicators:

$$Y_i = \sum_{h=1}^{P} w_{jh} * x_{jh} \quad (1)$$

The following equation illustrates a measurement model with composite indicators, where Y is a linear combination of indicators x_j, each weighted by an indicator weight w_j. In the second step, every latent variable was estimated by other latent variables by the following equation:

$$Z_j = \sum_{i \neq j}^{P} e_{ij} * y_i \quad (2)$$

where $e_{ij} = sign[cor(y_i, y_j)]$ and $w_{jh} = cor(Z_j, x_{jh})$

Next, we run the previous steps until convergence of the algorithm. Finally, we determined path coefficients by least squares regression.

After that, the structural model has been estimated as reliable and valid. Evaluating the R^2 for each endogenous latent variable is necessary. Tenenhaus et al. (2005) define the R^2 as follows:

$$R^2 = \sum \hat{\alpha}_j * \text{correl}(Y_j, x_j) \quad (3)$$

The R^2 with a higher level indicates a higher degree of predictive accuracy (Rigdon, 2014; Sarstedt et al., 2014).

3.2. Data and variables

This study employs an annual time series data for the period of 1996–2012 for 16 Middle East and North African (MENA) countries. The considered countries are Algeria, Bahreïn, Egypt, Iran, Iraq, Israel, Jordan, Lebanon, Libya, Malta, Morocco, Oman, Saudi Arabia, Syria, Tunisia and Yemen. The data are from the World development indicator (WDI) except for Corruption and Tax which are provided by the 2014 Economic Freedom Index from the Heritage Foundation. The variables used are as follows: carbon dioxide emissions (CO_2; metric tons per capita); GDP as a proxy of economic growth; corruption index (COR) the highest overall rating, theoretically 100, indicates the lowest corruption and the lowest rating (theoretically zero) indicate the highest corruption; fiscal freedom (TAX) and energy consumption (EC). Table 2 presents a summary statistics of the variables used in this study.

Table 2
Descriptive statistics of the selected items.

Latent variables	Indicateurs	Obs	Mean	Std. Dev.	Min	Max
Corruption	TAX	272	78.54559	19.2898	32.3	99.9
	COR	272	41.98162	21.6182	10	90
Energy	EC	272	3432.61	3471.246	223.97	12658.32
Pollution	CO_2	272	9.523346	9.262555	0.74	37.19
Economic growth	GPD	272	10255.39	11421.73	711.9649	47081.16

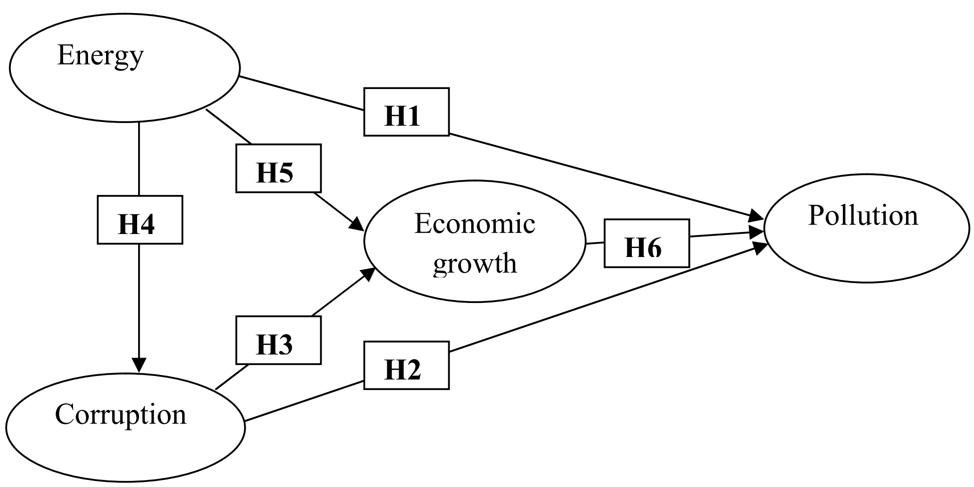

Fig.1. The structural model.

4. Results

4.1. Measurement model

To conduct empirical research and to test the proposed model (fig. 1). This paper calculates an estimated R^2 for the latent dependent variables with 300 iterations (Carlos, Davies, and Elms 2017). The variance explained by the model (R^2) is 66.9% for pollution, 34.9% for corruption, and 61.9% for economic growth. Additionally, the bootstrap approach with 5000 re-samples employed to validate our hypotheses (Hair et al., 2011). Furthermore, to conduct the previous procedure, internal consistency, reliability and discriminant validity is often assessed by way of three fundamental coefficients: Loadings, composite reliability and average variance (AVE). If the composite reliability (CR) value is above the threshold of 0.7, then this suggests that the construct reliability is acceptable. Table 3 indicates that all loading indicators and CR coefficients were higher than 0.7. These results show that the measurement model possessed acceptable reliability. In addition, the AVE measure being higher than 0.5 also confirms the existence of convergence validity. Fornell-Larcker criteria and the Heterottrait-Monotrait ratio of correlations were calculated in tables 3 and 4; the results confirm that the measures used in this study show evidence of satisfactory validity and reliability (Henseler, Ringle, and Sarstedt 2015).

Table 3

Assessment results of the measurement model.

Latent variable	Indicateur	Loading	CR	AVE
Energy	energy consumption (EC)	1.000	1.000	1.000
Pollution	carbon dioxide (CO_2)	1.000	1.000	1.000
Economic growth	Gross Domestic Product (GPD)	1.000	1.000	1.000
Corruption	Corruption (COR)	0.881	0.839	0.722
	fiscal freedom (TAX)	0.817		

Table 4

Discriminant validity assemssment.

Fornell-Larcker Criterion				
	Corruption	Economic growth	Energy	Pollution
Corruption	0.850			
Economic growth	0.586	1.000		
Energy	0.591	0.770	1.000	
Pollution	0.588	0.746	0.778	1.000
Heterotrait-Monotrait Ratio (HTMT)				
	Corruption	Economic growth	Energy	Pollution
Corruption				
Economic growth	0.732			
Energy	0.749	0.770		
Pollution	0.745	0.746	0.778	

Table 5

Structural relationships and hypotheses testing.

Hypotheses	Path coefficient	Standard Error	T-Statistic	P-Value	Result
Energy → Pollution	0.454	0.102	4.473	0.000	Supported (H1)
Corruption → Pollution	0.134	0.045	2.948	0.003	Supported (H2)
Corruption → Economic growth	0.201	0.045	4.471	0.000	Supported (H3)
Energy → Corruption	0.591	0.034	17.297	0.000	Supported (H4)
Energy → Economic growth	0.651	0.056	11.593	0.000	Supported (H5)
Economic growth → Pollution	0.318	0.115	2.760	0.006	Supported (H6)

In Table 5, we present the structural model results. All the path coefficients related to the inner relations are shown as unstandardized and their significance is assessed by the bootstrapping analysis (Tenenhaus et al., 2005). In particular, we obtain full support for H1 relative to the positive impact of energy on pollution ($\beta = 0.454$, $p<0.01$). Consequently, in line with current literature (Fredriksson and Neumayer, 2015; Farooq et al., 2013; Aghion et al., 2015). Similarly, the study discovered how corruption is positively related to pollution, and it is statistically significant at a 1% significance level. This development is found to be consistent with Zhang et al., (2016) who also reported that the Asia-Pacific Economic Cooperation countries with a long-run prevalence of corruption might the environment quality compared to the states without corruption. In addition, our result confirms the existence of a positive correlation between corruption and economic growth ($\beta = 0.201$, $p<0.01$). This shows that a 1% rise in corruption raises economic growth by 0.201% keeping other things constant. These findings are consistent with Adenike (2013), Dridi (2013) and Farooq et al. (2013) for Nigeria, Tunisia and Pakistan respectively. Specifically, Aparicio et al. (2016) argued that the control of corruption was fundamental to generating an opportunity for entrepreneurship and had a positive impact on economic growth. Similarly, Rock and Bonnett (2004) drew the conclusion that corruption reduced investment in most of the developing countries, but increased growth in the East Asian region. In our survey result, H3 finds the positive support of energy on pollution and statistically significant at 1% level. The 1% increase in energy consumption increases pollution by 0.454 in the MENA region. This result is consistent with Saidi and Hammami (2015) that showed a complementary with energy consumption and CO_2 emissions in 58 countries. The results of this study are in line with those of Esso and Keho (2016) who found that energy consumption has a positive impact on pollution in sub-Saharan countries.

Further results show that energy has a positive impact on corruption. H4 finds significant support at the level of 1%. This result is aligned with some previous contributions such as Fredriksson et al. (2004) and Fredriksson and Vollebergh (2009). In addition, we find full support for H5 with respect to the positive impact of energy consumption on economic growth ($\beta = 0.651$, $p<0.01$). The results here are consistent with those of a recent empirical study on this subject with Arezki and Brückner (2011), Saidi and Hammami (2015) and

Adams et al. (2016). On the other hand, the impact of economic growth on environmental quality was confirmed by the H6. In fact, we find full support ($\beta = 0.318$, $p<0.01$) in our results, which is similar to Ben et al. (2016) and Zhang et al. (2016).

4.2. Robustness checks

In this section, we analyze the presence of heterogeneity in the dataset that can potentially bias our results. However, observed and unobserved heterogeneity could be present in the sample (Ringle et al., 2005; Sarstedt and Ringle, 2010; Ringle et al., 2015; Ratzmann et al., 2016) and usually, the similar data characteristics are not respected. Failure to consider such heterogeneity can produce misleading PLS-SEM conclusions, leading to incorrect results (Becker et al., 2013; Rigdon et al., 2010). Among other methods, FIMIX-PLS analysis can control unobserved heterogeneity; the algorithm is run ten times for s = 2-5 segments (Hair and al., 2016a; Hair and al., 2016b).

As recommended by Hair et al. (2016b) in order to determine the optimal number of segments it is important to attempt the accompanying measures: Akaike's information criterion (AIC), Akaike's information modified AIC with factor 3 (AIC3), consistent AIC (CAIC), and the Normed Entropy Statistic (EN). Table 6 summarizes the results of the relevant retention criteria and suggests that a four-segment solution may be appropriate. In the next step, we partitioned the databases by assigning each observation to one of the four segments based on the maximum assignment probability (Sarstedt et al., 2011). Table 7 summarizes the results of the segment PLS path modeling results.

Table 6

Fit indices for a one- to five-segment solution.

S					Relative segment sizes π_s				
	AIC	AIC3	CAIC	EN	s=1	s=2	s=3	s=4	s=5
2	14 111.818	14 130.818	14 199.328	0.865	0.631	0.369			
3	13 928.205	13 957.205	14 061.773	0.774	0.400	0.322			
4	13 806.377	13 845.377	13 986.003	0.767	0.325	0.270	0.226	0.178	
5	13 782.178	13 831.178	14 007.862	0.830	0.326	0.256	0.247	0.107	0.063

Table 7

FIMIX-PLS results for the four-segment solutions.

Hypothesis	FIMIX-PLS			
	S = 1	S = 2	S = 3	S = 4
Energy → Pollution	0.950***	-0.029	0.428**	0.287
Corruption → Pollution	-0.030***	0.042	-0.007	0.592***
Corruption → Economic growth	0.098*	0.367***	0.027	0.178
Energy → Corruption	0.087	0.701***	0.664***	0.736***
Energy → Economic growth	0.872***	0.960***	-0.697***	0.356**
Economic growth → Pollution	0.057***	0.603***	0.999***	-0.304
R^2 (corruption)	0.008	0.492	0.441	0.542
R^2 (Economic growth)	0.785	0.883	0.272	0.359
R^2 (Pollution)	0.997	0.971	0.967	0.264
π_s	0.325	0.270	0.226	0.178
n_s	100	69	58	45

The results from the FIMIX-PLS (table 7) are much more persuasive. For example, the values for R^2 have been increased ranging between 78.5% (Economic growth) and 99.7% (Pollution) higher than in the global model. In addition, most path coefficients are significant at the 5 percent significance level and differ the four segments. Specifically, the empirical results indicate that there exists a long-run relationship between energy consumption and economic growth, this result is evident in the MENA region because most of the countries produce energy. Finally, the results with FIMIX-PLS provide a high degree of robustness in the case of unobserved heterogeneity (Esposito Vinci et al., 2007).

Table 8

Unit root test.

	ADF		PP	
	Intercept	Intercept and trend	Intercept	Intercept and trend
lnGDP	16.418	19.620	10.718	24.281
ΔLnGDP	39.618	26.720	85.672***	67.649***
$lnCO_2$	26.975	45.289*	34.153	42.454
Δln CO_2	107.216***	86.727***	209.847***	190.811***
lnEC	42.261	25.896	28.467	25.793
ΔlnEC	88.658***	68.904***	168.996***	166.067***
lnCOR	74.352***	64.245***	42.536*	40.237
ΔlnCOR	122.382***	81.179***	144.771***	125.436***
lnTAX	14.656	21.118	38.555*	43.290*
ΔlnTAX	81.777***	65.223***	169.540***	181.229***

Notes: Δ = Fist difference operator. ***, **,* denotes rejection of the null hypothesis of the presence of unit root in data series at 1%, 5%, and 10% level.

Tableau 9

Bound tests for the existence of Co-integration.

	Yearly data		Quarterly data	
Dependent Variable	F-Statistic	Cointegration	F-Statistic	Cointegration
F(CO_2\GDP,EC,TAX,COR)	8.172***	Yes	6.963***	Yes
F(CO_2\GDP, GDP^2, EC, TAX, COR)	7.046***	Yes	6.568***	Yes
F(GDP\CO_2, EC, COR, TAX)	2.884	No	1.519	No
F(COR\CO2, GDP, EC, TAX)	4.080**	Yes	2.247	No
Critical Value bounds	K=4		K=5	
Significance level	I(0)	I(1)	I(0)	I(1)
10%	2.45	3.52	2.26	3.35
5%	2.86	4.01	2.62	3.79
1%	3.74	5.06	3.41	4.68

Furthermore, the robustness for the long and short run among the variables can be achieved by Autoregressive Distributed Lag (ARDL) approach proposed by Pesaran and Shin (1999). In addition, we test the presence of environmental Kuznets curve (EKC) in our regression models. First, it is necessary to examine the stationary of each variable. In this context, we use Augmented- Dickey-Fuller (ADF) of Dickey and Fuller (1981) and Phillips-Perron (PP) of Phillips and Perron (1988) for the unit root tests. The results are reported in Table 8. We conclude that all the variables are integrated with first order I (1). Second, we examine the existence of cointegration relationship among the variables using the bounds test both for yearly and quarterly data. Table 9 described the results of this test. In the case of annual data, first, it can appear that when CO_2 is a dependent variable, the F-statistic is 8.172 that is greater than the upper bounds at 1% level of significance. This finding suggests that there is a cointegration relationship among pollution, economic growth, energy consumption and corruption. Thirdly, when the gross domestic product (GDP) is a dependent variable, there is no cointegration relationship among the variables (the F-statistic (2.884) is less than the lower bound critical value (3.52) at 10% significance level). Fourth, when corruption is a dependent variable, the F-statistic is higher than the lower bound critical value (4.01) at 5% level, implying the presence of cointegration relationship between the variables. For, the environmental Kuznets curve hypothesis, the F-statistic value (7.046) shows that there occurs a long-run relationship between the variables of the study. In quarterly data, the results are reported in Table 9. It is evident that the computed F-statistics exceed the 1% percent upper bounds of the critical values. Therefore, we may conclude that there is a cointegrating relationship among the variables when CO_2 as a dependent variable.

Table 10

Estimated long-run coefficient using ARDL approach.

	Yearly data					Quarterly data		
	(a)		(b)	(c)		(a)	(b)	
Dependent variable	$lnCO_2$	Causality	$lnCO_2$	lnCOR	Causality	$lnCO_2$	$lnCO_2$	Causality
$lnCO_2$	-	-	-	-0.396 (0.709)	No causality	-		-
lnGDP	0.109^{***} (0.005)	GDP → CO_2	-0.457 (0.946)	0.576^{**} (0.035)	GDP → COR	0.167^{***} (0.003)	-14.112 (0.281)	GDP → CO_2
lnEC	0.866^{***} (0.000)	EC → CO_2	0.866^{***} (0.000)	-0.102 (0.916)	No causality	0.790^{***} (0.000)	0.746 (0.000)	EC → CO_2
lnCOR	-0.06^{*} (0.063)	COR → CO_2	-0.06^{**} (0.066)	-	-	-0.075 (0.133)	-0.116 (0.038)	No causality
lnTAX	-0.015 (0.815)	No causality	-0.016 (0.810)	0.573 (0.228)	No causality	-0.010 (0.911)	-0.017 (0.850)	No causality
$lnGDP^2$	-	-	0.283 (0.920)	-	-	-	7.170 (0.275)	-
C	-5.486^{***} (0.000)	-		-2.443 (0.678)	-	5.361^{***} (0.000)	5.362*** (0.000)	-

Notes: (a) = F(CO_2\GDP,EC,TAX,COR), (b) = F(CO_2\GDP, GDP^2, EC, TAX, COR), (c) = F(COR\CO2, GDP, EC, TAX). *** Significant at 1% level. ** Significant at 5% level. * Significant at 10% level. P-value is reported in parentheses.

Table 11

Estimated short-run coefficient using ARDL approach.

	Yearly data					Quarterly data		
Dependent variable	lnCO_2	Causality	lnCO_2	lnCOR	Causality	lnCO_2	lnCO_2	Causality
DlnCO_2	-	-		0.478*** (0.001)	CO_2 → COR	-	-	-
D(lnCO_2(t-1))	-0.019 (0.743)	-	-0.018 (0.758)	-	-	-	-	-
D(lnCO_2(t-2))	-0.144** (0.0127)	-	-0.143 (0.013)**	-	-	-	-	-
D(lnEC)	0.764*** (0.000)	EC → CO_2	0.764*** (0.000)	0.360** (0.013)	EC → COR	0.917*** (0.000)	0.831*** (0.000)	EC → CO_2
D(lnEC(t-1))	-0.153** (0.016)	-	-0.154** (0.016)	-	-	-0.319** (0.028)	-0.267 (0.126)	-
D(lnEC(t-2))	0.163*** (0.002)	-	0.163*** (0.002)	-	-	0.085 (0.552)	0.068 (0.674)	-
D(lnEC(t-3))	-	-	-	-	-	0.261** (0.023)	0.350*** (0.005)	-
D(lnGDP)	0.149*** (0.000)	GDP → CO_2	-0.056 (0.978)	0.318*** (0.000)	GDP →COR	0.059 (0.589)	0.719 (0.830)	No causality
D(lnGDP(t-1))	-	-		-0.033 (0.428)	-	0.305** (0.031)	-1.336 (0.692)	-
D(lnGDP(t-2))	-	-	-	0.063** (0.040)	-	-0.078 (0.578)	9.723*** 0.005	-
D(lnGDP(t-3))	-	-	-	-	-	-0.248** (0.028)	-	-
D(lnGDP^2)	-	-	0.103 (0.921)	-	-	-	-0.277 (0.868)	-
D(lnGDP^2(t-1))	-	-	-	-	-	-	0.814 (0.630)	-
D(lnGDP^2(t-2))	-	-	-	-	-	-	-4.907 (0.004)	-
D(lnGDP^2(t-3))	-	-	-		-		-0.173*** (0.005)	-
D(lnCOR)	-0.062*** (0.010)	COR → CO_2	-0.062** (0.011)	-	-	-	-0.005 (0.908)	No causality
D(lnCOR(t-1))	-	-	-	-	-	-	0.078* (0.088)	-
D(lnTAX)	-0.005 (0.818)	No causality	-0.005 (0.811)	0.582*** (0.000)	TAX→ COR	-0.006 (0.911)	-0.108 (0.243)	No causality
D(lnTAX(t-1))	-	-	-	-	-	-	-0.068 (0.499)	-
D(lnTAX(t-2))	-	-	-	-	-	-	0.121* (0.088)	-
CointEq(-1)	-0.362*** (0.000)	-	0.363*** (0.000)	-0.124*** (0.000)	-	0.604*** (0.000)	-0.627*** (0.000)	-

Notes: (a) = F(CO_2\GDP,EC,TAX,COR), (b) = F(CO_2\GDP, GDP^2, EC, TAX, COR), (c) = F(COR\CO2, GDP, EC, TAX). *** Significant at 1% level. ** Significant at 5% level. * Significant at 10% level. P-value is reported in parentheses.

After identifying the co-integration relationship, we estimate the long-run relationship between variables using the ARDL model. Table 10 shows the results of ARDL approach. In yearly data, when CO_2 treated as dependent variable, GDP and energy consumption are positive and significant at 1% level of significance. If we check the relation of carbon dioxide emissions with corruption, it has negative and significant at 10% level of significance. However, the variable GDP and the square of GDP are non-significant in long-run that means that the EKC hypothesis is not valid for the MENA region and does not support the existence of the EKC hypothesis in contrast with Omri et al. (2015) who find the existence of environmental Kuznets curve in MENA countries. In quarterly data, the results of long-run relationship confirm the previous findings that GDP and EC sustain pollution in MENA region.

The short-run estimation results are described in Table 11. In yearly data, the coefficient of the error correction term is negative and significant for all models. Energy consumption and economic growth have a positive and significant contribution to CO2 emissions in line with Saidi and Mbarek (2015) indicating the vital relationship between GDP and carbon dioxide emissions CO_2. Corruption has an adverse and significant effect on pollution. Overall, short-run results are consistent with the long run. For quarterly data, we observe that only energy consumption has a positive and significant impact on CO_2 emissions. In addition, Table 11 reveals that all the error correction term (ETC) coefficients are negative and statistically significant at a 1% level. These findings confirm the long run relation between the variables. Moreover, coefficients of the error correction term give information about the appropriated time for adjustment after any shock to the equilibrium. The values of ECT that are varying between -0.362 and -0.627 mean that the speed of adjustment is moderate.

5. Conclusion

This paper has proposed an innovative model in order to examine the relationship between economic growth, energy consumption, corruption and pollution in the MENA region and also contributes to the previous empirical study by testing the interaction between all latent variables in the same model. According to the results of the estimation, it is shown that all hypotheses are supported. Firstly, the empirical results show that energy consumption and economic growth are associated with an increase in atmospheric pollution. Second, the findings exhibit that energy consumption has a significant and long-run relationship to economic growth. Thirdly, the results show that corruption has a positive impact on economic growth and contribute to an increase in CO2 emissions. Finally, results from PLS-SEM show a positive relationship between economic growth and pollution.

Despite some limitations, it is believed that the results of our study can be improved by increasing the sample of size, considering in particular data over a longer period and using more recent approach, such as PLS-POS and PLS-GAS when unobserved heterogeneity is present in the data.

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