ENERGY ECONOMICS LETTERS

http://aessweb.com/journal-detail.php?id=5049

RENEWABLE ENERGY CONSUMPTION, ECONOMIC GROWTH AND CO_2 EMISSIONS: EVIDENCE FROM SELECTED MENA COUNTRIES

Sahbi Farhani

University of Monastir, 5000 Monastir, Tunisia

FSEG Tunis, University of Tunis El Manar, 2092 Tunis El Manar II, Tunisia

LAMIDED, ISG Sousse, University of Sousse, 4000 Sousse, Tunisia

ABSTRACT

This paper uses panel cointegration techniques to examine the causal relationship between renewable energy consumption, economic growth and CO_2 emissions for a group of 12 MENA countries covering the annual period 1975-2008. The Granger-causality results indicate that there is no causal relationship between these variables in short run except a unidirectional causality running from renewable energy consumption to CO_2 emissions. However, we find unidirectional causality running from economic growth and CO_2 emissions to renewable energy consumption in long run. With panel FMOLS and DOLS estimates, we find that only CO_2 emissions have an impact on renewable energy consumption. These results indicate that MENA countries don't find the best policy which can control the regulation of the renewable energy prices, which can help to take into account the stability in the economic growth structure, and which can also mitigate pollutant emissions.

Keywords: Renewable energy consumption, Economic growth, CO_2 emissions, MENA countries

JEL Classification: C33, Q43

Corresponding Author: E-mail address: sahbi_1984@yahoo.fr. Tel.: +216 22833253

Citation: Sahbi Farhani (2013) "Renewable Energy Consumption, Economic Growth and Co2 Emissions: Evidence from Selected MENA Countries" Energy Economics Letters, 2013, Vol. 1, No.2, pp. 24-41.

1. INTRODUCTION

Due to the fact that energy is the vital source of the economic development and it directly pollutes the environment, the world could face an environmental catastrophe if precautions are not taken into consideration (Sims, 2004; DeCanio, 2009; Reddy and Assenza, 2009; Farhani and Ben Rejeb, 2012a). In this case, renewable energy can potentially play a pivotal role to increase energy supplies and to reduce emissions (Apergis et al., 2010). According to International Energy Agency (IEA, 2009), renewable energy accounted for 13.1% of world total primary energy supply in 2004 and offered significant opportunities for further growth that can facilitate the transition to a global sustainable energy supply by the middle of this century. Furthermore, the share of renewable energy in the electricity generation mix could increase from 18% in 2004 to 39% by 2050. If the global temperature rises to be limited between 2 °C and 2.4 °C, the renewable energy will serve a vital role to reduce 50% CO_2 emissions by 2050. In the historical literature, there are a few papers that found interesting results. Wisniewski et al. (1995), for example, proposed a method based on the efficiency energy coefficient for the assessment of renewable energy sources implementation and for the evaluation of their potential for CO_2 emissions reduction in Poland. In this study, energy coefficients were evaluated for renewable energy sources (such as solar, wind and biomass) as well as for their conventional substitutes based on coal, oil and gas. Relative coefficients for CO_2 emissions reduction were calculated in cases where particular conventional energy technology is replaced by appropriate renewable energy technology. This phenomenon led to ameliorate the optimal threshold parameter of the proportion of renewable energy and CO_2 emissions. For the case of European Union (EU), Boeters and Koornneef, (2011) investigated the climate policy strategy given by the European Council Spring Summit 2007 (EU Council, 2007).

The purpose of this paper is to test the interaction between renewable energy target and EU climate policy using the computable general equilibrium (CGE) model. This model makes possible to base the calibration directly on available estimates of costs and capacity potentials for renewable energy sources. Recently, Swaminathan and Tarun (2012) put points on what needs to be done in India by creating a pull from the market for renewable energy sources and by looking at the consumer behavior literature available in the area of diffusion of innovations. They conclude that demand for renewable energy sources from consumer communities must reach a tipping point quickly and for the sector to take-off on its own and become a self-sustaining business. In other way, Aune et al. (2012) consider the use of green certificates to reach the renewable targets and they analyze the potential for cost reductions by allowing for trade in green certificates across EU member states. The objective is to achieve 20% share of renewable energy in the EU's total energy consumption by 2020. Authors show that differentiated national targets cannot ensure a cost-effective implementation of the overall target for the EU's renewable energy consumption. The model suggested by Aune el al. (2012) indicates that EU-wide trade in green certificates may cut the EU's total cost of fulfilling the renewable target by as much as 70% compared with a case of absence of trade. For a large sample of countries, Apergis and Payne (2012) examine the relationship between real GDP, renewable energy consumption, non-renewable energy consumption, real gross fixed capital formation, and the labor force for 80 developed and developing countries. And they conclude that governments call, for more use of renewable and non-renewable energy, to step in to enhance the development of the renewable energy sector as well as explore the feasibility of implementing carbon taxes to reduce the use of non-renewable energy sources and greenhouse gas emissions.

The remainder of this paper is organized as follow: section 2 studies capacity of renewable energy in MENA region; section 3 investigates literature econometric review; section 4 describes data and descriptive statistics of these variables in MENA region; section 5 highlights econometrical methodology and empirical results; and the last one states conclusion and policy implications.

2. RENEWABLE ENERGY IN MENA REGION

Most of the region's greenhouse gas (GHG) emissions are linked largely to the region's role as an energy producer. IEA, (2009) estimates total GHG emissions from fuel combustion in MENA was equal to 1.860 million metric tons of CO_2 equivalent in 2008. These emissions accounted for roughly 6.3% of the global emissions from fuel combustion. By 2010, the emissions from the region's power sector are estimated to have risen to 2.101 million metric tons of CO_2 equivalent (World Bank, 2012). Table (1.A) reports the total renewable electricity net consumption measured in billion kilowatt-hours and CO_2 emissions from the consumption of energy measured in million metric tons per capita for a sample of 12 MENA countries covering the annual period 2006-2010. The total results reveal that the renewable electricity net consumption is not stable along this period while the per capita CO_2 emissions varies around 50 million metric tons per capita. For some countries, the consumption of electricity has a tendency to increase across time such as Algeria and Morocco. Algeria is the biggest consumer of electricity using renewable energy with Turkey a distant second. Their annual averages of electricity net consumption are 56.16% and 23.22% respectively. Cyprus and Israel are two smallest consumers of electricity with 0.01% and 0.03% respectively. Indeed, Israel and Cyprus are the two biggest in per capita CO_2 emissions from the energy consumption. Their annual averages of CO_2 emissions from the consumption are 19.11% and 17.50% respectively. We conclude that if the use of renewable energy increases, the rate of per capita CO_2 emissions will decrease. One of the most solutions is the use of renewable energy. But, the urgent challenge is how to use it; and how to turn the economy of the region into a sustainable path. Intergovernmental Panel on Climate Change (IPCC, **2011**) shows that the relatively large share of RE can be attributable not only from a single renewable resource, but to the deployment of a number of renewable resources. As with the rest of the world, MENA's rich endowment of renewable energy resources exceeds its annual energy needs. In 2010 the region's energy demand was approximately 1,121 TWh.

Table 1. *A. Total renewable electricity net consumption (billion kilowatt-hours) and CO_2 emissions from the consumption of energy (million metric tons per capita) for MENA countries*

	2006		***2007***		***2008***		***2009***		***2010***	
	EC	***CO2***	***EC***	***CO2***	***EC***	***CO2***	***EC***	***CO2***	***EC***	***CO2***
Alegria	94.993	2.872	96.829	3.032	97.648	3.164	102.109	3.283	110.904	3.207
Cyprus	0.001	9.077	0.003	8.889	0.014	9.190	0.010	8.713	0.121	8.395
Egypt	13.412	2.061	16.186	2.108	15.466	2.369	13.867	2.403	14.401	2.442
Iran	18.208	6.518	17.950	6.604	5.149	6.825	7.386	7.225	9.594	7.284
Iraq	6.035	3.431	5.679	3.592	3.450	3.704	3.195	3.746	4.718	3.987
Israel	0.025	9.990	0.024	9.890	0.025	9.399	0.097	9.497	0.145	9.562
Jordan	0.059	3.571	0.072	3.312	0.072	3.146	0.068	3.144	0.070	2.976
Lebanon	0.688	3.478	0.579	3.219	0.3690	3.629	0.616	3.760	0.831	3.694
Morocco	1.171	1.179	1.185	1.180	1.2180	1.203	2.933	1.197	4.092	1.128
Syria	3.906	2.696	3.443	2.591	284.000	2.571	1.847	2.700	2.566	2.843
Tunisia	0.129	2.090	0.092	1.965	0.069	2.089	0.175	1.840	0.189	1.768
Turkey	44.176	3.404	36.217	3.747	34.165	3.601	37.869	3.347	55.319	3.387
Total	182.803	50.367	178.259	50.129	160.485	50.89	170.172	50.855	202.95	50.673

Table 1. *B. Estimated renewable electricity potential (TWh per year) for MENA Countries*

	Hydro	***Wind***	***Biomass***	***Geothermal***	***Solar***
Alegria	0.5	35.0	12.3	4.7	135791.9
Bahrain	0.0	0.1	0.2	0.0	16.5
Djibouti	0.0	1.0	0.0	0.0	350.0
Egypt	50.0	125.0	14.1	25.7	57194.0
Gaza	0.0	0.5	1.7	0.0	28.0
Iran	48.0	12.0	23.7	11.3	32188.0
Iraq	67.0	20.0	8.8	0.0	24691.6
Israel	7.0	0.5	2.3	0.0	157.0
Jordan	0.1	5.0	1.6	0.0	5890.7
Kuwait	0.0	N.A	0.8	0.0	1375.8
Lebanon	1.0	1.0	0.9	0.0	10.0
Libya	0.0	15.0	1.8	0.0	82792.0
Malta	0.0	0.2	0.1	0.0	0.2
Morocco	4.0	35.0	14.3	10.0	8445.0
Oman	0.0	8.0	1.1	0.0	14178.1
Qatar	0.0	N.A	0.2	0.0	556.5
Saudi Arabia	0.0	20.0	10.0	70.9	75852.8
Syria	4.0	15.0	4.7	0.0	8466.3
Tunisia	0.5	8.0	3.2	3.2	5676.7
U.A.E	0.0	N.A	0.7	0.0	456.0
Yemen	0.0	3.0	9.1	107.0	8505.3
Total	182.1	304.3	111.6	232.8	462622.4

[a] *Source*: Energy Information Administration (EIA, 2011)

[b] *Source*: Fichtner (2011)

By 2050, this demand is approximately projected to reach 2,900 TWh (Fichtner, 2011). But only recently, renewable resources across the region have been accorded priority. Governments of the MENA countries make efforts to use this potential in order to require additional technological improvements, cost reductions, and the adoption of favorable policy regimes. The use of renewable energy (hydro, wind, biomass, geothermal, and solar) seems the greatest solution to reduce the severity of the environmental problems, to ensure the improvement of social welfare, and to innovate the green technology of the industrials firm's payoffs. The potential of the major renewable energy sources in the MENA Region is summarized below.

2.1. Hydroelectric Power

According to the recent World Bank (2012) report, the most commercially established renewable energy resource is the hydropower. This resource has been used to generate hydroelectricity. Traditionally this electricity power is generated along rivers by the force of flowing water and it remains the largest global renewable energy source. At present, hydropower supplies less than 2.5 % of the MENA region's electricity. The greatest technical potential for hydro development in the region can be found in Egypt, the Islamic Republic of Iran, and Iraq. Throughout the rest of the region, water scarcity cause serious problems in front of the hydroelectric for development potential. On the basis of the combined country-specific potential, if the countries exploit known hydropower resources using current technologies, the electricity will approximately generate 182.1 TWh per year (Table.1.B). The amount of this strategy can cover nearly 16 % of current electricity supplies in the region.

2.2. Wind Power

In the MENA Region, wind is being exploited along the coast of North Africa, especially in Morocco, Algeria, and Egypt. Although all of these countries have begun to apply programs, which can develop wind resources in the region, wind development will be taken up by other countries as well. The measurement results of World Bank, (2012) show that the total estimated economic potential of wind energy in the region is estimated at 304.3 TWh (Table.1.B). This means that the estimated wind potential of the region doubtless will increase if the wind exploration becomes more widespread and the technology improves to better harness lower-velocity wind speeds.

2.3. Biomass

Biomass productivity varies across the earth's surface. But biomass supplies in MENA countries are limited by the moisture deficit that shapes so much of life throughout the region. Historically, irrigation from the major river systems in Iraq (Tigris) and Egypt (Nile) relieved this constraint to biomass productivity. MENA's total biomass energy supplies are estimated at 111.6 TWh per year including agricultural waste, existing forest production, and municipal solid waste (see Table.1.B).

2.4. Geothermal Power

This power uses the temperature differential (exceeding 180°C) between the earth's surface and subsurface to turn water and steam to generate electricity. MENA's annual geothermal potential of the region is estimated at 232.8 TWh of electricity per year (Table.1.B). The most part of geothermal energy in MENA region is located in Algeria, Egypt, Iran, Morocco, Saudi Arabia, Tunisia, and Yemen.

2.5. Solar Energy

The World Bank's Report (2012) provides that MENA's potential solar energy is higher than in any other region in the world. In 2011, the distribution of solar energy striking the earth's surface exceeds 2000 kWh per m² per year throughout the region. The estimation of MENA's solar energy potential is calculated from the sum of concentrating solar power and photovoltaic power. The estimated concentrating solar power comes to over 462266.4 TWh per year and the estimated photovoltaic power represents 356 TWh per year. This means 462622.4 TWh per year of MENA's solar power (Table.1.B).

3. LITERATURE ECONOMETRIC REVIEW

There are a few studies that have focused on the causal relationship between renewable energy consumption, economic growth and CO_2 emissions (see for example Sadorsky, 2009; Apergis et al., 2010; Menyah and Wolde-Rufael, 2010). Sadorsky, (2009) estimates an empirical model of renewable energy consumption, CO_2 emissions and oil prices for the G7 countries from 1980 to 2005 using panel vector error correction model (VECM). Panel cointegration techniques estimates show that in long term, GDP per capita and emissions are two major drivers behind renewable energy per capita. In the short term, changes in renewable energy consumption per capita are driven mostly by movements back to long term equilibrium as opposed to short term shocks. In other work, Apergis et al. (2010) examine the causal relationship between CO_2 emissions, renewable energy, nuclear energy and economic growth for a group of 19 developed and non-developed countries for the period 1984-2007. They find a long-run and positive relationship between emissions and renewable energy consumption. Whereas, the results from the panel Granger causality tests suggest that renewable energy consumption does not contribute to reduce CO_2 emissions in the short-run. In the same way, Menyah and Wolde-Rufael (2010) explore the causal relationship between CO_2 emissions, renewable and nuclear energy consumption and real GDP for the US for the period 1960-2007. The empirical evidence indicates a unidirectional negative causality running from nuclear energy consumption to CO_2 emissions and proves that nuclear energy consumption can help to reduce CO_2 emissions. In contrast, they found no causality running from renewable energy consumption to CO_2 emissions but they also found a unidirectional causality running from CO_2 emissions to renewable energy consumption. In conclusion, the econometric evidence seems to suggest that nuclear energy consumption can help to mitigate CO_2 emissions, but so far, renewable energy consumption has not reached to obtain a significant contribution to emissions reduction.

4. DATA AND DESCRIPTIVE STATISTICS

4.1. Data

The data set is a balanced panel of 12 MENA countries followed over the years 1975-2008 and includes annual data on renewable energy consumption (REC), economic growth (GDP), and CO_2 emissions (CO_2) converted into natural logarithms to reduce the heterogeneity. Renewable energy consumption is measured in metric tons of oil equivalent. GDP per capita is measured in constant 2000 US$ and CO_2 emissions is measured in metric tons per capita. The 12 MENA economies included in the sample are: Algeria, Cyprus, Egypt, Iran, Israel, Jordan, Morocco, Saudi Arabia (SA), Sudan, Syria, Tunisia, and Turkey. These data are obtained from the World Bank Development Indicators (WDI).

In this case, the long-run relationship between renewable energy consumption, GDP per capita and CO_2 emissions will be given by the following equation:

$$LNREC_{i,t} = \alpha_i + \beta_i LNGDP_{i,t} + \gamma_i LNCO2_{i,t} + \varepsilon_{i,t} \quad (1)$$

where i, t, α_i and $\varepsilon_{i,t}$ denote the country, the time, the fixed country effect and the white noise stochastic disturbance term, respectively. β_i and γ_i are the renewable energy consumption elasticities of GDP and CO_2 emissions, respectively (all variables are in natural logs, denoted LN).

4.2. Descriptive statistics

The analysis begins with descriptive statistics of variables used in the sample of 12 MENA countries (Table-2). Then, we investigate the variables time series plots (in logarithms form) for each country (Fig 1, Fig 2, Fig 3 and Table-2).

Table-2. *Descriptive statistics*

	LNREC	***LNGDP***	***LNCO2***
Mean	1.938637	3.369214	0.412810
Median	2.010610	3.249163	0.493542
Maximum	4.081163	4.341259	1.251617
Minimum	-0.316953	2.385147	-0.992868
Std. Dev.	1.279493	0.476682	0.468638
Skewness	0.175549	0.300659	-0.842382
Kurtosis	1.629683	2.492212	3.852329
Jarque-Bera	34.01765	10.53033	60.60317
Probability	0.000000	0.005169	0.000000
Observations	408	408	408
Cross sections	12	12	12

Fig 1 shows time series plots of log renewable energy consumption for each of the countries. Sudan is the biggest renewable energy consumer and Syria is the smallest. However, most of countries have an increase and trends upwards across time, except Turkey have decreased from the 90's. Fig 2 shows time series plots of log GDP per capita of each country. In fact, all most countries have increased across time in GDP per capita except Saudi Arabia has a drop from 80's. Israel is the biggest GDP per capita while Sudan and Egypt are the smallest. Fig 3 shows time series plots of log CO_2 emissions per capital of each country. Practically, almost countries have increased across time in CO_2 emissions. However, Algeria, Israel, Saudi Arabia and Sudan have some fall across time. In spite of the drop of CO_2 emissions in Saudi Arabia, it still the largest polluting country, whereas, Sudan is the smallest (see Appendix).

Table-3 shows the average annual growth rates for each variable over 1975-2008. We although find that the average annual growth rate for renewable energy consumption vary between countries and range from a low of -79.23% in Saudi Arabia, to a high of 60.21% in Syria. For all countries, all values do not exceed 5% per year except Syria. This result confirms that most of these countries do not invest in green technologies using renewable energy. In fact, some countries, such as Egypt, Cyprus and Tunisia, stand out for having a high economic growth. Thereby, the average annual of renewable energy consumption in these countries is similar to their average annual growth rate in GDP per capita. It means that renewable energy consumption is growing at about the same rate as economic growth. In Syria, the average annual growth rate for renewable energy consumption is important and growing more rapidly than economic growth rate. Egypt and Tunisia are two countries that have a positive average annual growth rate in CO_2 emissions while Sudan has the lower and negative value of growth rate in CO_2 emissions.

Table 3. *Average annual growth rates over 1975-2008*

Country	*Renewable energy consumption*	*GDP per capita*	*CO2 per capita*
Algeria	1.80	0.11	2.91
Cyprus	2.79	0.47	1.97
Egypt	0.36	0.49	45.7
Iran	0.53	0.02	1.24
Israel	4.99	0.19	0.00
Jordan	-42.7	0.33	4.87
Morocco	0.55	0.28	5.49
SA	-79.2	-0.14	0.52
Sudan	0.18	0.29	-0.25
Syria	60.2	0.20	4.55
Tunisia	0.47	0.35	18.5
Turkey	-0.12	0.27	3.31
Total	-4.18	0.24	7.41

5. ECONOMETRICAL METHODOLOGY AND EMPIRICAL RESULTS

This section sets out the analytical framework underlying our empirical modeling strategy. This strategy begins with the examination of the stationarity properties of the respective variables employing a battery of panel unit root tests, latter it consists to determine whether or not the variables are cointegrated, and finishing with special estimates to assume our model.

5.1. Panel unit root analysis

In this paper, two types of panel unit root test are computed in order to assess the stationary of the variables including Levin et al. (LLC, 2002) and Im et al. (IPS, 2003) tests. Levin et al. (LLC, 2002) propose a panel based on the augmented Dickey–Fuller (ADF) test that assumes homogeneity in the dynamics of the autoregressive coefficients for all panel units with cross-sectional independence.

They consider the following equation:

$$\Delta X_{it} = \alpha_i + \beta_i X_{i,t-1} + \delta_i t + \sum_{j=1}^{k} \gamma_{ij} \Delta X_{i,t-j} + \varepsilon_{it} \quad (2)$$

where Δ is the first difference operator, X_{it} is the dependent variable, ε_{it} is a white-noise disturbance with a variance of σ_{ε}^2, i indexes country, and t indexes time. The test involves the null hypothesis $H_0 : \beta_i = 0$ for all "i" against the alternative $H_1 : \beta_i \prec 0$ for all "i". Im et al. (IPS, 2003) test is not restrictive as Levin et al. (LLC, 2002) test, since it allows for heterogeneous coefficients. The null hypothesis is that all individuals follow a unit root process, $H_0 : \beta_i = 0$ for all i. The alternative hypothesis allows some of the individuals to have unit roots, then: $H_1 : \begin{cases} \beta_i < 0 \text{ for i=1,...,N}_1 \\ \beta_i = 0 \text{ for i=N}_1\text{+1,...,N} \end{cases}$. The test is based on the averaging individual unit root test $\bar{t} = \frac{1}{N}\sum_{i=1}^{N} t_{\beta_i}$. The results of these tests are reported in Table-4 which indicate that each variable is integrated of order one, I(1).

Table 4. *Panel unit root test results*

Method		LNREC	LNGDP	LNCO2
LLC-t*:	Level	-1.32891 (0.0919)	-2.46346 (0.0069)**	-3.39589 (0.0003)**
	Δ	-1.59088 (0.0000)**	-11.1596 (0.0000)**	-20.6107 (0.0000)**
IPS-W-stat:	Level	-1.03539 (0.1502)	-0.79857 (0.2123)	-2.53424 (0.0056)
	Δ	-17.2492 (0.0000)**	-13.6386 (0.0000)**	-19.5161 (0.0000)**

Variables REC, GDP and CO2 are expressed in natural logarithm (LN). Levin et al. (LLC, 2002) and Im et al. (IPS, 2003) examine the null hypothesis of non-stationary.
Δ is the first difference operator.
** denotes statistical significance at the 5% level.
Lag selection (Automatic) based on Schwarz Information Criteria (SIC).

5.2. Panel cointegration tests

We employ two types of tests, i.e. Pedroni (2004) and Kao (1999) tests. The panel cointegration tests results of Pedroni (2004) and Kao (1999) are presented in Table-5 and Table-6, respectively. Pedroni, (2004) proposes two cointegration tests based on the within approach which includes four statistics (panel tests) and on the between approach which includes three statistics (group tests). In total, there are seven statistics for the tests of the null hypothesis of no cointegration in heterogeneous panels (for more details see: Farhani and Ben Rejeb, 2012b). However, all these tests are based on the residual and variants of Phillips and Perron (PP, 1988) and Dickey and Fuller (ADF, 1979). Table-5 shows Pedroni's (2004) results indicate that we reject null hypothesis of cointegration at the 5% significance level except group rho-statistic. Kao (1999)'s residual cointegration tests are presented in Table-6, which reject null hypothesis of cointegration relationship between renewable energy consumption, GDP per capita and CO_2 emissions at the 5% significance level.

Table 5. *Pedroni (2004)'s cointegration test (LNREC as dependent variable)*

	Test statistic	Prob.		Test statistic	Prob.
Within-dimension			**Between-dimension**		
Panel υ-stat	3.299995**	0.0005			
Panel r-stat	-5.044325**	0.0000	Group r-stat	-1.092690	0.1373
Panel PP-stat	-11.82522**	0.0000	Group PP-stat	-6.798553**	0.0000
Panel ADF-stat	-12.20453**	0.0000	Group ADF-stat	-6.505088**	0.0000

Critical value at the 5% significance level denoted by **.
The test includes intercept and trend.
The null hypothesis is that the variables are not cointegrated.
Lag length selected based on SIC automatically with a max lag of 7.

Table 6. *Kao (1999)'s residual cointegration test (LNREC as dependent variable)*

	t-statistic	Prob.
ADF	3.562501**	0.00002

The null hypothesis indicates that the variables are not cointegrated.
** indicates statistical significance at the 5% level.

5.3. Panel causality test

A panel-based on error correction model (ECM) followed by the two steps of Engle and Granger, (1987) is employed to investigate the long-run and short-run dynamic relationships. The first step estimates the long-run parameters in equation (1) in order to obtain the residuals corresponding to the deviation from equilibrium. The second step estimates the parameters related to the short-run adjustment. The resulting equations are used in conjunction with panel Granger causality testing:

$$\Delta LNREC_{i,t} = \theta_{1,i} + \sum_{k=1}^{m} \theta_{1,1,i,k}.\Delta LNREC_{i,t-k} + \sum_{k=1}^{m} \theta_{1,2,i,k}.\Delta LNGDP_{i,t-k} + \sum_{k=1}^{m} \theta_{1,3,i,k}.\Delta LNCO2_{i,t-k} + \lambda_{1,i}.ECT_{i,t-1} + u_{1,i,t} \quad (3)$$

$$\Delta LNGDP_{i,t} = \theta_{2,i} + \sum_{k=1}^{m} \theta_{2,1,i,k}.\Delta LNREC_{i,t-k} + \sum_{k=1}^{m} \theta_{2,2,i,k}.\Delta LNGDP_{i,t-k} + \sum_{k=1}^{m} \theta_{2,3,i,k}.\Delta LNCO2_{i,t-k} + \lambda_{2,i}.ECT_{i,t-1} + u_{2,i,t} \quad (4)$$

$$\Delta LNCO2_{i,t} = \theta_{3,i} + \sum_{k=1}^{m} \theta_{3,1,i,k}.\Delta LNREC_{i,t-k} + \sum_{k=1}^{m} \theta_{3,2,i,k}.\Delta LNGDP_{i,t-k} + \sum_{k=1}^{m} \theta_{3,3,i,k}.\Delta LNCO2_{i,t-k} + \lambda_{3,i}.ECT_{i,t-1} + u_{3,i,t} \quad (5)$$

where the term Δ denotes first differences; $\theta_{j,i,t}$ (j=1,2,3) represents the fixed country effect; k (k=1,…,m) is the optimal lag length determined by the Schwarz Information Criterion; and $ECT_{i,t-1}$ is the estimated lagged error correction term (ECT) derived from the long-run cointegrating relationship of equation-1. The term $\lambda_{j,i}$ (j=1,2,3) is the adjustment coefficient and $u_{j,i,t}$ is the disturbance term assumed to be uncorrelated with zero means. We definite the lagged residuals estimated in equation-6 as the ECT, and then we estimate the parameters related to the short-run equation:

$$ECT_{i,t} = LNREC_{i,t} - \hat{\beta}_i LNGDP_{i,t} - \hat{\delta}_i LNCO2_{i,t} \tag{6}$$

Table 7. *Panel causality test results*

Dependent Variable	***Sources of causation (Independent variable)***			
	Short run			***Long run***
	ΔLNREC	***ΔLNGDP***	***ΔLNCO2***	***ECT***
ΔLNREC	#	0.29475 (0.7449)	1.47785 (0.2294)	-0.058136 (0.0008)**
ΔLNGDP	1.99968 (0.1367)	#	0.10983 (0.8960)	-0.011596 (0.1994)
ΔLNCO2	3.26307 (0.0393)**	0.80360 (0.4484)	#	-0.001064 (0.9520)

** indicates statistical significance at the 5% level.
P-value listed in parentheses.

Table -7 reports the results of short-run and long-run Granger-causality test. With respect to equation-3, only CO_2 emissions have a positive and significant influence on the renewable energy consumption. Renewable energy consumption will not be explained by GDP growth and CO_2 emissions. The ECT is statically significant only for renewable energy consumption equation. It means that long-run adjustment to equilibrium is important in explaining short run movements in renewable energy consumption.

5.4. Panel FMOLS and DOLS estimates

Although OLS estimators of the cointegrated vectors are super convergents, their distribution is asymptotically biased and depends on nuisance parameters associated with the presence of serial correlation in the data (see, Pedroni, 2001 and Kao and Chiang, 2001). Such problems, existing in the time series case, also arise for the panel data and tend to be more marked even in the presence of heterogeneity (See in particular Kao and Chiang, 2001). To carry out tests on the cointegrated vectors, it is consequently necessary to use methods of effective estimation. Various techniques exist, such as Fully Modified Ordinary Least Squares (FMOLS) initially suggested by Philips and Hansen (1990) or the method of Dynamic Ordinary Least Squares (DOLS) of Saikkonen (1991) and Stock and Watson (1993). In the case of panel data, Kao and Chiang (2001) showed that these two techniques led to normally distributed estimators, it means that both

OLS and Fully Modified OLS (FMOLS) exhibit small sample bias and that DOLS estimator appears to outperform both estimators. Similar results are got by Phillips and Moon (1999) and Pedroni (2001) for method FMOLS.

Our empirical model is based on the regression between these three variables as presented in equation-1, where the renewable energy consumption and the economic growth slopes β_i with as well as the renewable energy consumption and the CO_2 emissions slopes δ_i, which may be homogeneous across i:

$$LNREC_{i,t} = \alpha_i + \beta_i.LNGDP_{i,t} + \delta_i.LNCO2_{i,t} + \sum_{k=-K_i}^{K_i} \phi_{i,k}.\Delta LNGDP_{i,t-k} + \sum_{k=-K_i}^{K_i} \varphi_{i,k}.\Delta LNCO2_{i,t-k} + \varepsilon_{i,t} \quad (7)$$

Table 8. *Renewable energy consumption long-run elasticities*

	LNGDP		***LNCO2***	
Country	***FMOLS***	***DOLS***	***FMOLS***	***DOLS***
Algeria	-0.480970	-0.217879	0.398338	1.634609
	(0.8811)	(0.9503)	(0.0616)	(0.3639)
Cyprus	0.262806	0.368278	0.993762	0.702439
	(0.8573)	(0.8049)	(0.6367)	(0.7436)
Egypt	1.106800	0.902827	0.993762	-0.049570
	(0.0001)**	(0.0008)**	(0.6367)	(0.8115)
Iran	-1.123140	-1.070447	1.645929	1,575696
	(0.0042)**	(0.0041)**	(0.0000)**	(0.0000)**
Israel	2.152158	2.465080	0.527003	0.290399
	(0.0000)**	(0.0000)**	(0.1159)	(0.4624)
Jordan	-0.275106	-0.656351	2.425477	2.291109
	(0.6817)	(0.4819)	(0.0000)**	(0.0003)**
Morocco	-0.640015	-0.315898	1.489410	1.307144
	(0.0863)	(0.4034)	(0.0000)**	(0.0000)**
SA	-0.640015	-1.959459	0.800459	0.776539
	(0.0863)	(0.0008)**	(0.3588)	(0.3967)
Sudan	1.153714	1.039669	-0.58190	-0.353850
	(0.0001)**	(0.0017)**	(0.0024)**	(0.1027)
Syria	1.235299	1.271500	1.219534	1.089485
	(0.0139)**	(0.0080)**	(0.0001)**	(0.0001)**
Tunisia	1.122136	1.195371	0.173486	0.095446
	(0.0000)**	(0.0000)**	(0.2406)	(0.4845)
Turkey	-1.992719	-1.762365	1.230842	1.051221
	(0.0000)**	(0.0000)**	(0.0000)**	(0.0000)**
Panel	0.463923	0.433105	-2.281982	-2.236330
	(0.2835)	(0.3415)	(0.0000)**	(0.0000)**

Asymptotic distribution of t-statistic is standard normal as T and N → ∞.
** Indicates that the parameter is significant at the 5% level.
P-value listed in parentheses.

Table-8 reported the results of the individual and panel FMOLS and DOLS. The estimated coefficients from the long-run cointegration relationship can be interpreted as long-run elasticities. Beginning with the country specific result, we find that GDP have a significant impact on the renewable energy consumption for most of countries except Algeria, Cyprus, Jordan and Morocco, under both

FMLOS and DLOS individual test. In fact, for Egypt, Israel, Sudan, Syria and Tunisia, GDP has a positive and statistically significant effect on renewable energy consumption. However, for Iran, Saudi Arabia, and Turkey, the impact of GDP on renewable energy consumption is negative and statistically significant at the 5% level. Turning the effect of CO_2 emissions on renewable energy consumption, we find that for Iran, Jordan, Morocco, Syria, and Turkey, CO_2 emissions have a positive and statistically significant impact on renewable energy, under FMOLS and DOLS individual test. While, for Sudan the impact of CO_2 emissions on renewable energy consumption is negative and statistically significant at the 5% level, under FMOLS individual tests. Under both FMOLS and DOLS panel estimates, we find that only CO_2 emissions elasticity is negative and significant at the 5% level, which means that with increase in CO_2 emissions, demand of renewable energy decreases. The long-run CO_2 emissions elasticities under FMOLS and DOLS are -2,281% and -2,236%, respectively. These results prove that most of these countries don't use renewable energy because the investment costs in green technologies are very expensive, so government does not encourage economies to adopt the clean technologies using renewable energy.

6. CONCLUSION AND POLICY IMPLICATIONS

We attempted to find the linkages among renewable energy consumption, economic growth and carbon emissions in 12 MENA countries from 1975 to 2008. To specify what matter, we used panel unit root, panel cointegration methods and panel Granger causality test. Our panel cointegration tests reveal the existence of a panel long- run equilibrium relationship between renewable energy consumption, economic growth, and CO_2 emissions. It means that these three variables move together in the long run. To study the causal relationship between these variables, we employed Engle and Granger (1987)'s test which examines the long-run and the short-run dynamic relationship. In sum, our empirical results show that there is no causal relationship between these variables in the short-run except one relation running from renewable energy consumption to CO_2 emissions. An important emerging result from the short-run causality test shows that renewable energy consumption plays a vital role in reducing CO_2 emissions. Furthermore, we can say that the policies may stabilize economic growth and income with attempting to consume more efficient energy. The long-run dynamics displayed by the error correction terms from equations 3-5, reveal that renewable energy consumption, economic growth and CO_2 emissions respond to deviations from long-run equilibrium given the statistical significance of their respective ECT. We deduce that only the estimated coefficient of ECT in the renewable energy consumption equation is significant, implying that renewable energy consumption could play an important adjustment factor as the system departs from the long-run equilibrium. The policymakers should then take into consideration the degree of economic growth in each country when renewable energy consumption policy is formulated. In this case, policy makers should encourage a multilateral effort to promote renewable energy and to reduce CO_2 emissions in the region. Regional cooperation on the development of renewable energy markets between public and private sector stakeholders could begin with sharing information across countries with respect to on-going projects, technologies, as well as financing and investment strategies (Apergis and Payne, 2010). The impact of GDP on renewable energy consumption is not significant, while there are slight positive effects of GDP on energy consumption. In the long-run, 1% increase in CO_2 emissions decreases renewable energy consumption by approximately 2.28% and 2.23% for FMOLS and DOLS panel estimates, respectively. The econometric evidence seems to suggest that, contrary to the results founded by Apergis et al. (2010) and Menyah and Wolde-Rufael (2010), renewable energy consumption play an important role in reducing CO_2 emissions. In addition, pollution can be reduced if governments: i) take into account globalization (Leitão, 2013), ii) improve the industrial sector by importing cleaner technology to attain maximum gain from international trade i.e., the inclusion of trade openness in the general model can mitigate emissions (Halicioglu, 2009; Jalil and Mahmud, 2009; Jayanthakumaran et al., 2012; Shahbaz et al., 2012; Tiwari et al., 2013), and iii) decline CO_2 emissions through effective implementation of economic policies and financial development improves environment i.e., reduces CO_2 emissions by redirecting the resources to environment friendly projects (Shahbaz et al., 2013).

For future research, studies can focus on the inclusion of the trade openness and the index of globalization in order to attain a comprehensive impact of economic growth, renewable and non-renewable energy consumption, trade openness and globalization on CO_2 emissions which will provide new insights to policy makers in controlling environmental degradation.

REFERENCES

Apergis, N., Payne, J.E., 2010. Renewable energy consumption and growth in Eurasia. Energy Economics, 32, 1392-1397.

Apergis, N., Payne, J.E., 2012. Renewable and non-renewable energy consumption-growth nexus: Evidence from a panel error correction model. Energy Economics, 34, 733-738.

Apergis, N., Payne, J.E., Menyah, K., Wolde-Rufael, Y., 2010. On the causal dynamics between emissions, nuclear energy, renewable energy, and economic growth. Ecological Economics, 69, 2255-2260.

Aune, F.R, Dalen, H.M., Hagem, C., 2012. Implementing the EU renewable target through green certificate markets. Energy Economics, 34, 992-1000.

Boeters, S., Koornneef, J., 2011. Supply of renewable energy sources and the cost of EU climate policy. Energy Economics, 33, 1024-1034.

DeCanio, S.T., 2009. The political economy of global carbon emissions reductions. Ecological Economics, 68, 915-924.

Dickey, D.A., Fuller, W.A., 1979. Distribution of the estimators for autoregressive time series with a unit root. Journal of the American Statistical Association, 74, 427-431.

Energy Information Administration, EIA, 2011. EIA, International Energy Statistics.

http://www.eia.gov/cfapps/ipdbproject/iedindex3.cfm?tid=6&pid=29&aid=2&cid=regions,&syid=2006&eyid=2010&unit=BKWH

Engle, R.F., Granger, C.W.J., 1987. Co-integration and error correction: Representation, estimation, and testing. Econometrica, 55, 251-276.

EU Council, 2007. Council of the European Union: Brussels European Council, Presidency Conclusions. http://register.consilium.europa.eu/pdf/en/07/st07/st07224-re01.en07.pdf

Farhani, S., Ben Rejeb, J., 2012a. Energy consumption, economic growth and CO_2 emissions: Evidence from panel data for MENA region. International Journal of Energy Economics and Policy, 2, 71-81.

Farhani, S., Ben Rejeb, J., 2012b. Link between economic growth and energy consumption in over 90 countries. Interdisciplinary Journal of Contemporary Research in Business, 3, 282-297.

Fichtner, 2011. MENA Regional Water Outlook, Part II, Desalination Using Renewable Energy, Final Report. http://wrri.nmsu.edu/conf/conf11/mna_rdrens.pdf

Im, K.S., Pesaran, M.H., Shin, Y., 2003. Testing for unit roots in heterogeneous panels. Journal of Econometrics, 115, 53-74.

Intergovernmental Panel on Climate Change, IPCC, 2011. Working Group III of the Intergovernmental Panel on Climate Change, in: Edenhofer, O., Pichs-Madruga, R., Sokona, Y., Seyboth, K., Matschoss, P., Kadner, S., Zwickel, T., Eickemeier, P., Hansen, G., Schlömer, S., von Stechow, C. (Eds.), Special Report on Renewable Energy Sources and Climate Change Mitigation. Cambridge University Press, New York. http://srren.ipcc-wg3.de/report/IPCC_SRREN_Full_Report.pdf.

International Energy Agency, IEA, 2009. World Energy Outlook, Paris, France.

Leitão, N.C., 2013. The environmental Kuznets curve and globalization: The empirical evidence for Portugal, Spain, Greece and Ireland. Energy Economics Letters, 1, 15-23.

Kao, C., 1999. Spurious regression and residual-based tests for cointegration in panel data. Journal of Econometrics, 90, 1-44.

Kao. C., Chiang, M.H., 2001. On the estimation and inference of a cointegrated regression in panel data, in: Baltagi B.H., Fomby, T.B., Hill, R.C. (Eds.), Nonstationary Panels, Panel Cointegration, and Dynamic Panels (Advances in Econometrics, Volume 15). Emerald Group Publishing Limited, pp. 179-222.

Levin, A., Lin, C.F., Chu, C.S., 2002. Unit root tests in panel data: Asymptotic and finite-sample properties. Journal of Econometrics, 108, 1-24.

Menyah, K., Wolde-Rufael, Y., 2010. CO_2 emissions, nuclear energy, renewable energy and economic growth in the US. Energy Policy, 38, 2911-2915.

Pedroni, P., 2001. Purchasing power parity tests in cointegrated panels. The Review of Economics and Statistics, 83, 727-731.

Pedroni, P., 2004. Panel cointegration: Asymptotic and finite sample properties of pooled time series tests with an application to the PPP hypothesis. Econometric Theory, 20, 597-625.

Phillips, P.C.B., Hansen, B.E., 1990. Statistical inference in instrumental variables regression with I(1) processes. Review of Economic Studies, 57, 99-125.

Phillips, P.C.B., Moon, H.R., 1999. Linear regression limit theory for nonstationary panel data. Econometrica, 67, 1057-1112.

Phillips, P.C.B., Perron, P., 1988. Testing for a unit root in time series regressions. Biometrika, 75, 335-346.

Reddy, B.S., Assenza, G.B., 2009. The great climate debate. Energy Policy, 37, 2997-3008.

Sadorsky, P., 2009. Renewable energy consumption, CO2 emissions and oil prices in the G7 countries. Energy Economics, 31, 456-462.

Saikkonen, P., 1991. Asymptotically efficient estimation of cointegration regressions. Econometric Theory, 7, 1-21.

Shahbaz, M., Lean, H.H., Shabbir, M.S., 2012. Environmental Kuznets Curve hypothesis in Pakistan: Cointegration and Granger causality. Renewable and Sustainable Energy Reviews, 16, 2947-2953.

Shahbaz, M., Mutascu, M., Azeem, P., 2013. Environmental Kuznets Curve in Romania and the role of energy consumption. Renewable and Sustainable Energy Reviews, 18, 165-173.

Sims, R.E.H., 2004. Renewable energy: a response to climate change. Solar Energy, 76, 9-17.

Stock, J.H., Watson, M.W., 1993. A simple estimator of cointegrating vectors in higher order integrated systems. Econometrica, 61, 783-820.

Swaminathan, M., Tarun, D., 2012. Diffusion of innovation model of consumer behaviour – Ideas to accelerate adoption of renewable energy sources by consumer communities in India. Renewable Energy, 39, 162-165.

Tiwari, A.K., Shahbaz, M., Hye, Q.M.A., 2013. The Environmental Kuzents Curve and the role of coal consumption in India: Cointegration and causality analysis in an open economy. Renewable and Sustainable Energy Reviews, 18, 519-527.

Wisniewski, G., Rogulska, M., Grzybek, A., Pietruszko, S.M., 1995. The role of renewable energy in carbon dioxide emission reduction in Poland. Applied Energy, 52, 291-298.

World Bank, 2012. Renewable energy desalination: An emerging solution to close the water gap in the Middle East and North Africa (MENA development report). http://www-wds.worldbank.org/external/default/main?pagePK=64187835&piPK=64620093&theSitePK=523679&menuPK=64187283&siteName=WDS&sType=2&dAtts=DOCDT,DOCNA,REPNB,LANG,DOCTY,VOLNB,REPNME&sortDesc=DOCDT&query=renewable%20energy%20consumption%20in%20MENA

APPENDIX

Fig 1. *Natural log of renewable energy consumption for 12 MENA countries*

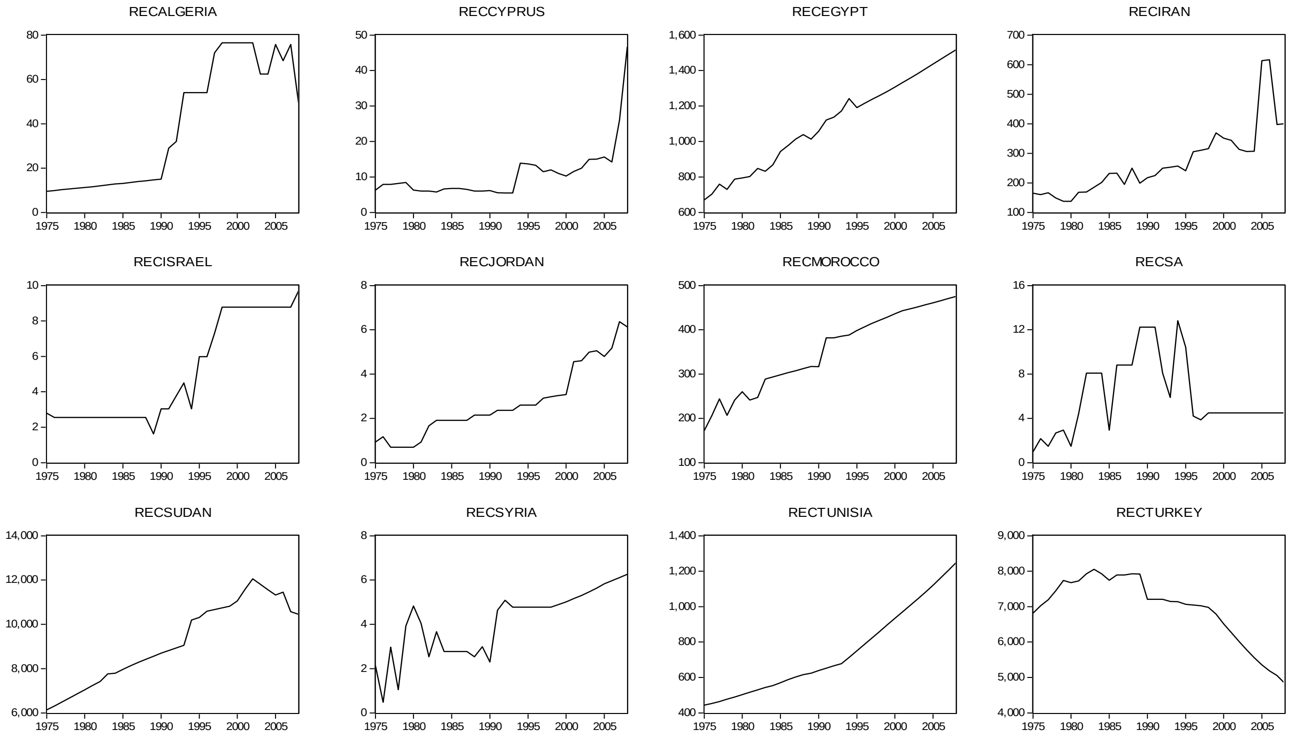

Fig 2. *Natural log of GDP per capita for 12 MENA countries*

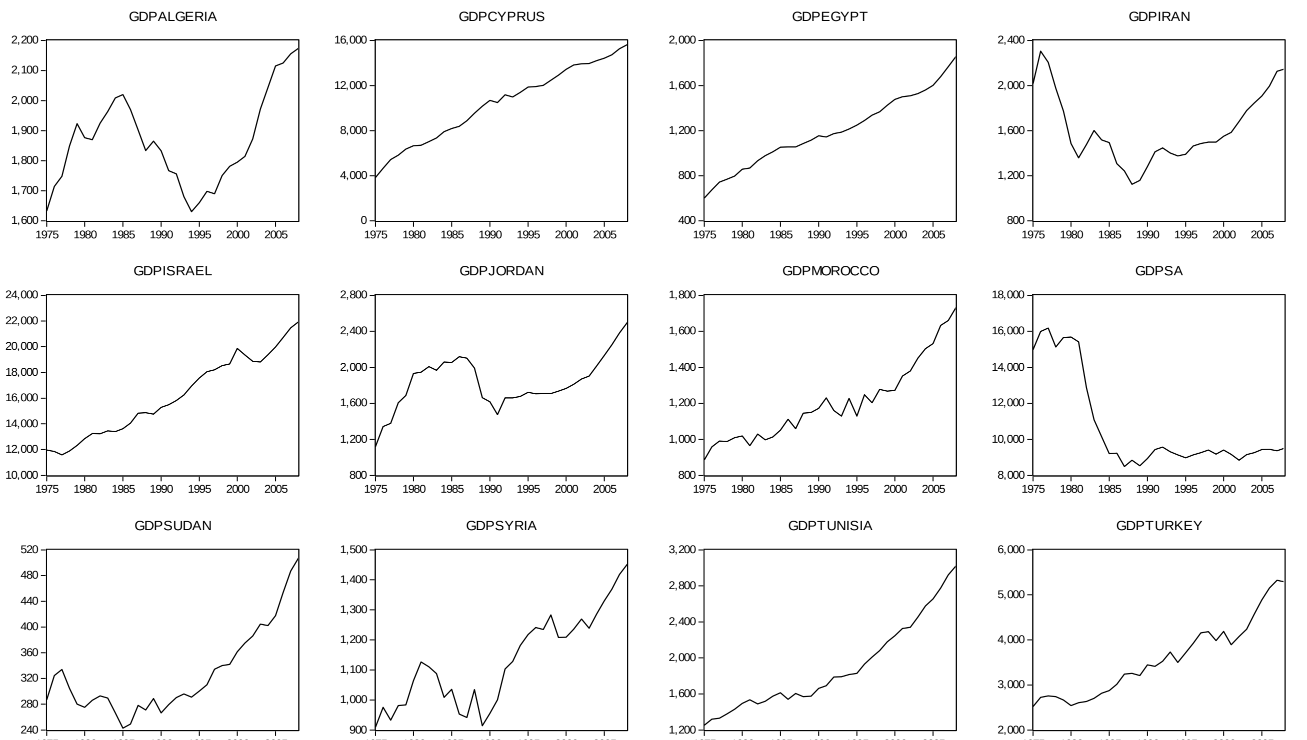

Fig 3. *Natural log of CO_2 emissions per capita for 12 MENA countries*