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Energy Consumption and Economic Growth in the Middle East and North Africa: A Multivariate Causality Test

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Abstract

Using a panel data Vector Error Correction model (VECM), this paper investigates the relationship between output and its main determinants including energy consumption in the Middle East and North Africa (MENA) over the period 1987-2008 within a multivariate framework. More specifically, the model allows us to examine the short- and long-run causal relationship between energy consumption and output growth when we control for the presence of capital and labor inputs. The result confirms the existence of a long-run equilibrium relationship among real GDP, energy consumption, fixed capital formation, and employment. The panel Granger causality tests reveal that there is bidirectional causal relationship between real GDP and energy consumption. Our finding hence supports the feedback hypothesis. The result suggests that an energy-conservation policy might adversely affect output growth in MENA. This finding may have important policy implications for policymakers and international organizations. Furthermore, the Generalized Method of Moments (GMM) is used to estimate the long-run elasticities. The estimation results show that the elasticity of real GDP with respect to energy consumption is 0.38. Moreover, a 1% increase in real GDP raises energy consumption by 0.60% in this region. We might conclude that an energy policy that results in the improvements of energy efficiency not only helps to conserve energy consumption but also boosts the economic output in these countries.

Keywords: Energy–growth relationship; Granger causality; Panel Vector Error Correction; MENA
JEL classifications*:* C22; Q43; Q48

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1. Introduction

Since the first oil shock in the early 1970s the role of energy consumption in output growth has become the focus of many economic researches. Energy has a direct link to a country's GDP through consumption, investment, exports and imports and hence can affect all components of aggregate demand. Given a positive relationship between energy consumption and economic growth, a negative shock to energy, such as an increase in energy prices or energy conservation policies will negatively affect real GDP.

Since the work of Kraft and Kraft (1978) for the United States, numerous researchers have examined the causal relationship between energy consumption and output growth for various countries and regions. Most researchers have used time series analysis to study the causality between energy use and real GDP for an individual country.

The empirical result on causal relationship between energy consumption and output growth is mixed. There are many studies that found unidirectional causality running from GDP to energy consumption. These include Kraft and Kraft (1978), Yu and Choi (1985), Abosedra and Baghestani (1989), Cheng and Lai (1997), Soytas and Sari (2003), Lee (2006), Zamani (2007), Chiou-Wei et al. (2008), Lee and Chien (2010).

In contrast, many researchers such as Yu and Choi (1985), Stern (1993, 2000), Soytas and Sari (2003), Oh and Lee (2004), Lee (2006), Adeniran (2008), Belloumi (2009), Lee and Chien (2010) showed that the causality runs from energy consumption to real GDP.

The above findings were challenged by many authors who found bidirectional causality between energy use and real GDP many. They include Yang (2000), Soytas and Sari (2003), Ghali and El-Sakka (2004), Oh and Lee (2004), Lee (2006), and Belloumi (2009).

At the other extreme, Akarca and Long (1980), Yu and Hwang (1984), and Cheng (1995), Masih and Masih (1996), Lee (2006), Payne (2009), Lee and Chien (2010) and Ozturk and Acaravci (2011) found no causal relationship between energy consumption and output growth.[1]

All of the above studies have used time series analysis and focused on an individual country. More recently some researchers have investigated the causal relationship between energy consumption and economic growth in the context of panel data models. According to Baltagi (2005), the use of panel data model has several advantage over using cross section or time series models. Panel data control for individual heterogeneity and also give more informative data, more variability, less collinearity among the variables and more efficiency. Furthermore, panel data models are better able to examine the dynamics of adjustment. Finally, they have advantage over

1. For a literature survey on energy–growth nexus see Ozturk (2010).

cross-section or time-series models in constructing and testing more complicated behavioral models.

The findings of panel data models are also mixed. For example, the papers that found unidirectional causality running from GDP to energy consumption include Lee and Chang (2007), Mehrara (2007), Huang et al. (2008), and Ozturk et al. (2010).

Lee and Chang (2007) studied the interaction between energy consumption per capita and real GDP per capita in 22 developed and 18 developing countries. They found unidirectional causality running from real GDP to energy consumption in developing countries. Mehrara (2007) found a unidirectional causality from economic growth to energy consumption for a panel of 11 selected oil exporting countries and. Huang et al. (2008) used panel data analysis to study this causal relationship in 82 countries. They divided the countries into four categories: low income group, lower middle income group, upper middle income group, and high income group. They showed that there is unidirectional causality running from output growth to energy consumption in both the middle and high income groups. Ozturk et al. (2010) found the same relationship in high income countries.

The researchers that showed that the causality runs from energy consumption to GDP for a panel of countries are Lee (2005), Lee and Change (2010), Narayan and Smyth (2008), Apergis and Payne (2009), Nondo and Kahsai (2009), and Apergis and Payne (2010a).

Lee (2005) used panel data error correction model to study energy-GDP relationship for 18 developing countries. He showed that the causality runs from energy consumption to GDP for these countries. Lee and Change (2010) used a multivariate framework for 16 Asian countries and found a long-run unidirectional causality running from energy use to economic growth. However, they found no short-run causal relationship between these two variables.

Narayan and Smyth (2008) used a panel data Vector Error Correction Model (VECM) and showed that fixed capital formation and energy consumption Granger cause real GDP in the long run for a panel of G7 countries. Apergis and Payne (2009) used a panel data error correction model to study this relationship for six Central American countries within a multivariate framework. They also showed that the causality runs from energy consumption to economic growth in these countries. Nondo and Kahsai (2009) found the same result for a panel of 19 African countries (COMESA). Apergis and Payne (2010a) used an Error Correction Model (ECM) within a multivariate framework to study the relationship between energy consumption and economic growth for a panel of nine South American countries. They confirmed the existence of long-run equilibrium relationship between real GDP, energy consumption, labor force, and real gross fixed capital formation in these countries. Their results also revealed that the causality runs from energy consumption to economic growth in these countries.

The papers that used panel data analysis and found bidirectional causality between energy consumption and GDP include Lee and Chang (2007), Mishra et al. (2009), Ozturk et al. (2010), Apergis and Payne (2010b), Apergis and Payne (2010c), and Eggoh et al. (2011).

Lee and Chang (2007) found a bidirectional causality between real GDP and energy consumption for a group of 22 developed countries. Mishra et al. (2009) also confirmed the same result for a panel of 9 Pacific Island countries. Ozturk et al. (2010) examined this causality for low and middle income countries and showed that there exists a bidirectional causal relationship between these two variables in the middle income economies.

Apergis and Payne (2010b) studied the relationship between natural gas consumption and economic growth for a panel of 67 countries and found a short- and long-run bidirectional causality between these variables. Apergis and Payne (2010c) also examined the relationship between renewable energy consumption and economic growth for a panel of twenty OECD countries and found bidirectional causality between renewable energy consumption and economic growth in these countries. Eggoh et al. (2011) studied the relationship between energy use and output growth for a group of 21 African countries and found a long-run equilibrium relationship among energy consumption, real GDP, prices, labor and capital in these countries. Moreover, the result confirmed the existence of bidirectional causal relationship between energy and output growth.

Finally, there are authors that found no causal relationship between energy consumption and GDP in the context of panel data models. For example, Lee and Change (2008) studied the causality between energy consumption and economic growth in16 Asian countries and found no short-run causal relationship between these two variables.[1] Huang et al. (2008) [2] also examined this causality for 82 countries and found no relationship between energy consumption and output growth in the low income group.

The empirical studies on energy-growth relationship preclude the Middle East and North Africa (MENA) as a block. According to World Bank reports (2003), about 57 percent of the proven world oil reserves and about 41 percent of the proven world natural gas reserves are in the Middle East and North Africa. Many energy-rich countries such as Saudi Arabia, Iran, Iraq, Kuwait and Qatar are located in this region and a high percentage of their

1. However, they found a long-run unidirectional causality running from energy consumption to economic growth in these countries.
2. Based on the income levels defined by the World Bank, these authors divided the countries into four income groups.

international trade is devoted to oil and gas exports. For example, Iran which possesses about 10 percent of proven world oil reserves and the second largest country in the world in terms of natural gas reserves is located in this region. Undoubtedly, this region is a key world energy pool.

The region faces some big challenges too. It has one of the highest population growth rates and experiences a relatively low job creation. According to the World Bank, high unemployment has been a problem in MENA for years. High population growth and urbanization rates require more energy consumption.[1]

The question is how energy consumption interacts with output growth in MENA. Moreover, one might be interested to know whether limiting energy use through energy conservation policy would slow down economic growth, investment and employment in this region. To answer these questions, it is important to know the direction of causal relationship between real output and energy consumption in this energy-rich region.

To the best of our knowledge, no research has used multivariate panel Granger causality to study the interaction among gross domestic product (GDP), energy consumption, fixed capital formation, and labour force in MENA as a block. The main goal of this paper is to fill this gap in the empirical literature. To this end, we follow Apergis and Payne (2009, 2010a, 2010b and 2010c) and use a panel data Vector Error Correction Model (VECM) to investigate the short- and long-run causality between real output and its main determinants including energy consumption in the Middle East and North Africa within a multivariate framework. Provided a long-run causal relationship exists between the variables, we use the Generalized Method of Moments (GMM) to estimate the long-run elasticity of real GDP (energy consumption) with respect to energy consumption (real GDP).

Our findings may have important policy implications for policymakers, economists and international organization in this resource-rich region in which most countries depend heavily on their revenue from exporting oil and gas and also suffer from relatively high level of unemployment and low economic growth.[2] The article contains four sections. After the introduction, the model is presented in Section two. Section three is devoted to data description and results. The final section is the concluding remarks.

2. Theory and Model

Early neoclassical growth models considered capital and labor as primary factors of production and ignored the role of energy in economic growth. Energy was mostly considered as an intermediate input. The negative impact

1. World Bank reports (2003, 2007).
2. The result of this paper might be useful for policymakers in Iran and other MENA countries in conducing policies that affect the main determinants of growth rate in this region.

of the oil shocks of early 1970s and 1980s on output, employment and investment showed the importance of energy for economic growth. In fact energy is an input that cannot be produced or recycled from any other input.[1] Hence, many researchers such as Hall et al. (1986) argue that labor and capital are intermediate factors of production and energy is the primary factor of production.

In the literature on energy-output relationship, one can find four different hypotheses: growth; conservation; feedback; and neutrality hypotheses. The growth hypothesis emphasizes on both the direct and indirect role of energy in production. According to this hypothesis energy consumption leads to output growth. Hence, an energy conservation policy will have negative impact on real output and employment and may harm economic growth. The conservation hypothesis underlines the importance of energy conservation. According to this hypothesis the causality runs from real gross domestic product (GDP) to energy consumption. It implies that an increase in output causes an increase in energy use. The feedback hypothesis argues that energy consumption and real GDP are interdependent and hence suggests there is a bilateral causal relationship between them. According to this hypothesis a shock to either one of these variables affects the other. Finally, the neutrality hypothesis argues that there is no causal relationship between energy consumption and output. It claims that energy consumption has little impact on output and hence does not play an important role in production process. Hence, an energy conservation policy does not affect real GDP.[2]

As will be explained shortly we follow Apergis and Payne ((2009), (2010a)) to study the relationship among output growth, energy consumption, investment and employment in MENA. Prior to presenting our panel data vector error correction model, we use Ghali and El-Sakka (2004) to introduce energy into the following continuous monotonic quasi concave neoclassical one-sector production function:

$$\mathrm{Y_t} = f(K_t, L_t, E_t), \qquad \frac{\partial Y}{\partial K} > 0,\ \frac{\partial Y}{\partial L} > 0,\ \frac{\partial Y}{\partial \mathrm{E}} > 0. \tag{1}$$

In which Y, K, L, and E are real domestic gross production (GDP), capital stock, level of labor force and total energy consumption, respectively. The subscript *t* denotes the time period. After taking the differential of Eq. (1) and doing some simplification we obtain:

$$\dot{\mathrm{Y}}_\mathrm{t} = a\dot{K}_t + b\dot{L}_t + c\dot{E}_t,\ a = \frac{\partial \mathrm{f}}{\partial \mathrm{K_t}}\frac{\mathrm{K_t}}{\mathrm{Y_t}}, \mathrm{b} = \frac{\partial \mathrm{f}}{\partial \mathrm{L_t}}\frac{\mathrm{L_t}}{\mathrm{Y_t}}, \mathrm{c} = \frac{\partial \mathrm{f}}{\partial \mathrm{E_t}}\frac{\mathrm{E_t}}{\mathrm{Y_t}}. \tag{2}$$

In which dot on top of each variable denotes the growth rate of that variable and *a*, *b*, and *c* are elasticity of output with respect to capital, labor, and energy, respectively.

1. Stern (1999), page 382.
2. For more details see Apergis and Payne (2009) and Lorde et al. (2010).

Equation (1) describes a long run relationship between output and inputs. Hence, it allows to examine the presence of long run equilibrium relationship among these variables using a multivariate cointegration framework. If we introduce the lagged values of variables into above equations, we might also examine the short-run dynamics of the model. The short-run behavior provides us with useful information about the role of each input in predicting the change of real output and vice versa. Hence, it allows us to study the causal relationship among variables using a multivariate Granger-causality test.[1]

However, the direction of causality among the variables in equation (2) is not resolved yet. Most empirical works have focused on bi-variate Granger causality test between output and energy and ignored the role of investment and employment in their models. This might be a source of specification error in the models. To overcome this shortcoming, we follow the recent literature and use a multivariate Granger causality test to study the relationship among the mentioned variables for a block of MENA countries.

Given our goal, we follow Apergis and Payne ((2009), (2010a)) and use Engle and Granger (1987) and Granger (1988) and among others to construct and estimate a panel data Vector Error Correction Model (VECM). It allows us to study the short- and long-run causal relationship among growth rates of real output, investment, employment and energy consumption.[2] The following equation is used to study the long run relationship among the variables.

$$\mathrm{LY_{it}} = \rho_0 + \rho_1 \mathrm{LE_{it}} + \rho_2 \mathrm{LK_{it}} + \rho_3 \mathrm{LL_{it}} + \varepsilon_{\mathrm{it}},\ i=1,\ldots,\mathrm{N} \text{ and } t=1,\ldots,\mathrm{T}. \quad (3)$$

In which LY is the logarithm of real domestic gross product, LE is the logarithm of energy usage, LK is the logarithm of fixed capital formation and LL is the logarithm of labour force. The subscript *i* stands for country *i=1,...,N* and *t* for time period, *t=1,...,T*. $\varepsilon_{\mathrm{it}}$ is the disturbance term and ρs are the parameters. Equation (3) represents a long run relationship among variables.

Provided a long-run equilibrium relationship exists among the variables, we estimate the following vector error correction model (VECM):

$$\Delta LY_{it} = \mu_{1j} + \sum_{j=1}^{q} \alpha_{1j} \Delta LY_{it-j} + \sum_{j=1}^{q} \beta_{1j} \Delta LE_{it-j} + \sum_{j=1}^{q} \gamma_{1j} \Delta LK_{it-j} + \sum_{j=1}^{q} \theta_{1j} \Delta LL_{it-j} + \lambda_{1i} ECT_{it-1} + u_{1it} \quad (4a)$$

$$\Delta LE_{it} = \mu_{2j} + \sum_{j=1}^{q} \alpha_{2j} \Delta LY_{it-j} + \sum_{j=1}^{q} \beta_{2j} \Delta LE_{it-j} + \sum_{j=1}^{q} \gamma_{2j} \Delta LK_{it-j} + \sum_{j=1}^{q} \theta_{2j} \Delta LL_{it-j} + \lambda_{2i} ECT_{it-1} + u_{2it} \quad (4b)$$

1. See Ghali and El-Sakka (2004), page 228.
2. This approach is also used by Adjaye (2000), Lee (2005), Mishra et al. (2009), Narayan and Smyth (2008), Oh and Lee (2004), Soytas and Sari (2003).

$$\Delta LK_{it} = \mu_{3j} + \sum_{j=1}^{q} \alpha_{3j} \Delta LY_{it-j} + \sum_{j=1}^{q} \beta_{3j} \Delta LE_{it-j} + \sum_{j=1}^{q} \gamma_{3j} \Delta LK_{it-j} + \sum_{j=1}^{q} \theta_{3j} \Delta LL_{it-j} + \lambda_{3i} ECT_{it-1} + u_{3it} \quad (4c)$$

$$\Delta LL_{it} = \mu_{4j} + \sum_{j=1}^{q} \alpha_{4j} \Delta LY_{it-j} + \sum_{j=1}^{q} \beta_{4j} \Delta LE_{it-j} + \sum_{j=1}^{q} \gamma_{4j} \Delta LK_{it-j} + \sum_{j=1}^{q} \theta_{4j} \Delta L_{it-j} + \lambda_{4i} ECT_{it-1} + u_{4it} \quad (4d)$$

In which $\mu, \alpha, \beta, \gamma, \theta$ and λ are parameters, *ECT* is error correction term, Δ denotes the first difference of a variable and $u_{4it}, u_{3it}, u_{2it}$ and u_{1it} are the disturbance terms. We are now ready to estimate the short and long-run models.

In order to study the causal relationships between energy consumption, economic growth, fixed capital formation and labour force we first examine whether each variable contains a unit root. If the variables are not stationary, the second step is to test whether there is a long run cointegration relationship among the variables. If a long-run relationship between the variables is found, the next step is to estimate a panel vector error correction model to examine the existence of the short- and long-run Granger causality between the variables.

More specifically, prior to examine the causality, we should estimate the long run model (i.e., equation (3)). Provided a long-run equilibrium relationship exists among the variables, we use the first lag of estimated disturbance term (ε_{it-1}) obtained from equation (3) and substitute it for ECT in equations (4a)-(4d) and estimate our vector error correction model. The Wald test is used to examine short-run Granger causality between variables. For example, in order to test whether real GDP Granger causes energy consumption in the short run, we estimate equation (4a) and test the null hypothesisH_0: $\beta_{1j} = 0,\ j = 1,2,3, \ldots, q$. If H_0 is rejected, it means that energy consumption Granger causes real GDP. Similarly, in order to see whether real GDP causes energy consumption we estimate equation (4b) and test the null hypothesis H_0: $\alpha_{2j} = 0,\ j = 1,2,3, \ldots, q$. If H_0 is rejected, it means that real GDP Granger causes energy consumption. Provided the null hypotheses for both equations (i.e. equations (4a) and (4b)) are rejected, we conclude that there is a bilateral causality between real output and energy consumption. However, if H_0 is rejected for one but accepted for the other, it means there is unidirectional causality. Finally, provided that the two null hypotheses are not rejected, there is no Granger causality between these two variables. Similar reasoning can be used for other pair of variables and other equations. Moreover, if ECT in one equation is statistically significant, it implies that there is also a long-run causality between the variables in that equation.

If a long-run causal relationship is found between the variables, we estimate the long-run models to obtain the elasticities. Given the possible correlation between the dependent variables and the disturbances in our long-run model, the OLS method is no longer unbiased and consistent.[1] The use of Generalized Method of Moments (GMM) will allow us to get rid of any endogeneity that may arise due to correlation between the individual effects and the explanatory variables. Moreover, the GMM method can be made robust to heteroscedasticity and autocorrelation. This method allows us to select the parameters so that the correlation between the disturbance and a set of instruments closes to zero.

3. Data Description and Results

Annual data are obtained from the World Development Indicators (WDI, 2011) for seventeen MENA countries. The data cover the 1987-2008 period. LY is natural logarithm of real gross domestic product (GDP) in US dollar (2000), LE is the log of total energy usages in equivalent kilo ton of crude oil. LK is the log of gross fixed capital formation in US dollar (at constant price of 2000), LL is log of employment. Hence, ΔLX_{it} is the growth rate of variable X in country *i* at time*t* .

Prior to our estimation we use panel data unit root test proposed by Im, Pesaran and Shin (IPS) (2003) to examine whether the variables are stationary. The optimal lag for this test is chosen based on Schwarz criterion (SIC). The result of IPS panel data unit root test is reported in Table (1).

Table 1. IPS panel data unit root test

variable	with constant and without trend t-bar statistic		with constant and trend t-bar statistic	
	Level	First difference	Level	First difference
LY	7.4312	-12.3379[a]	-1.2212	-9.6978[a]
LE	5.0508	-15.0142[a]	-0.2181	-12.856[a]
LK	5.2551	-8.6539[a]	0.4016	-8.6212[a]
LL	3.4909	-3.2554[a]	1.1425	-2.4642[a]

[a] indicates statistical significance at 1 percent level or less.

The result of panel unit root test shows that LY, LE, LK, and LL are not stationary at level. However, their first differences are stationary. It means that all variables are integrated of order one, I(1). In order to avoid the spurious regression we have to examine whether a long-run equilibrium relationship exists among these variables. We use Pedroni ((1999), (2004)) Panel PP, Panel ADF, Group PP, and Group ADF statistics to examine the presence of cointegration relationship among the variables. The results of Pedroni tests within dimension and between dimension for both constant

1. For more detail see Hsiao (2003), page73.

term without trend and constant term with trend tests are reported in Table (2).

Table 2. Pedroni cointegration test

	within dimension: Test Statistic			between dimension: Test Statistic	
	with constant	with constant and trend		with constant	with constant and trend
Panel PP-stat	-3.6770[a]	-4.8405[a]	Group PP-stat	-3.4975[a]	-4.6155[a]
Panel ADF-stat	-4.4200[a]	-6.1531[a]	Group ADF-stat	-4.1832[a]	-6.6397[a]

[a] indicates statistical significance at 1 percent level or less.

The lag length for Pedroni test is selected based on SIC. The results of Pedroni test show that the null hypothesis of no cointegration relationship among LY, LE, LK, and LL is rejected. It means that there is a long-run equilibrium relationship among these variables and hence there is no room for possible spurious regression.[1]

The next step is to estimate the vector error correction model. In order to choose between fixed and random effects model, we conduct the Hausman test. A central assumption in random effects estimation is that the random effects are uncorrelated with the explanatory variables.[2] If the null hypothesis of no correlation is rejected, the use of random effects method becomes inconsistent. The result of Hausman test is reported in Table 3. According to this result, the null hypothesis is not accepted. Hence, we use the fixed effects method to estimate the model.

Table 3. Hausman test

Period	χ^2	Prob.
1987-2008	8.6524[a]	0.03

[a] indicates statistical significance at 5% level.

More specifically, feasible Generalized Least Squares (GLS) in the context of cross section SUR with fixed effects method is used to estimate the VECM (the equations (4a)-((4b)). The error correction term, ECT(-1) is the first lag of estimated disturbance term obtained from the estimation of the long run model (i.e., equation (3)). The estimation results of equations (4a)-(4d) are reported in Table 4.[3]

1. We have also used Kao (1999) residual cointegration test. This test also confirms the existence of long-run relationship among variables. The result of this test is not reported here but is available upon request.
2. Baltagi (2005), page 66.
3. Given our limited sample period, we started with three lags, and find out that the models with 2 lags give the most appropriate results. The lag length is chosen by Schwarz criterion.

Table 4. The estimation result of the VECM

Dependent Variable/coefficients	Δ LY	Δ LE	Δ LK	Δ LL
Intercept	0.0359[a]	0.0588[a]	0.0111[a]	0.0364[a]
Δ LY(-1)	-0.1564[a]	0.1271[a]	0.1769[a]	0.1083[a]
Δ LE(-1)	0.2447[a]	0.0400	-0.0973[a]	-0.0530[a]
Δ LK(-1)	0.0577[a]	-0.0511[a]	-0.0084	-0.0024[a]
Δ LL(-1)	0.7893[a]	0.1965	1.1398[a]	0.1726[a]
Δ LY(-2)	-0.0637[a]	-0.1114[a]	0.0012	0.0544[a]
Δ LE(-2)	-0.1516[a]	-0.2592[a]	0.0472[a]	-0.0708[a]
Δ LK(-2)	0.0432[a]	0.1228[a]	-0.1161[a]	-0.0072[a]
Δ LL(-2)	-0.5330[a]	-0.2364[a]	0.1798[a]	-0.0040
ECT(-1)	-0.2304[a]	0.2337[a]	0.0865[a]	0.0094[a]
Adjusted R-squared	0.97	0.70	0.91	0.9480
F-statistic	389.44[a]	30.49[a]	138.3660[a]	235.8887[a]
Durbin-Watson stat	2.15	2.07	2.03	2.06

[a] indicates statistical significance at the 1% level or less.

Next, we apply the Wald test to the estimated coefficients of lagged explanatory variables of equations (4a)-(4d) to investigate the short-run Granger causality. We start with the estimation result of equation (4a) (the second column of Table 4). In order to examine whether the short-run Granger causality is running from energy consumption, investment, and employment to LY, we test the null hypotheses of $\mathrm{H_0}: \beta_{1j} = 0,\ \mathrm{H_0}: \gamma_{1j} = 0, \mathrm{H_0}: \theta_{1j} = 0\ ,\ \ j = 1{,}2,$ respectively. The results are reported in Table 5. As it can be seen from the table, the null hypotheses of no short-run causality are rejected for all cases. Hence, we confirm the existence of short-run causality running from LE, LK, and LL to LY. It means that energy consumption, fixed capital formation, and labor force can be used to predict real GDP in MENA countries.

Table 5. Short run causality when Δ LY is dependent variable

Dependent Variable Δ LY	F-statistic	Causality direction
$\mathrm{H_0}: \beta_{1j} = 0, \quad j = 1{,}2$	1382.794[a]	LE⟹LY
$\mathrm{H_0}: \gamma_{1j} = 0, \quad j = 1{,}2$	275.0011[a]	LK⟹LY
$\mathrm{H_0}: \theta_{1j} = 0, \quad j = 1{,}2$	456.2677[a]	LL⟹LY

[a] indicates statistical significance at the 1% level or less.

Next, we use the estimation result of equation (4b) (the third column of Table 4) to examine the Granger causality when LE is dependent variable. The results of Wald test for this equation is reported in Table 6. The results indicate that the null hypotheses of $H_0: \alpha_{2j} = 0$, $H_0: \gamma_{2j} = 0, H_0: \theta_{2j} = 0$, $j = 1{,}2$, are rejected. Hence, we conclude that a short-run causality runs from LY, LK, and LL to LE. This means that real GDP, fixed capital formation and labor force play an important role in predicting energy consumption.

Table 6 . Short run causality when Δ LE is dependent variable

Dependent Variable Δ LE	F-statistic	Causality direction
$H_0: \alpha_{2j} = 0, \quad j = 1,2$	21.0785[a]	LY⟹LE
$H_0: \gamma_{2j} = 0, \quad j = 1,2$	102.5785[a]	LK⟹LE
$H_0: \theta_{2j} = 0, \quad j = 1,2$	3.8680[b]	LL⟹LE

[a] indicates statistical significance at the 1% level or less. [b] indicates statistical significance at the 2% level.

Similarly, the estimation result of equation (4c) (the forth column of Table 4) is used to study the Granger causality between the variables when LK is dependent variable. The result of Wald test applied to the coefficients of lagged independent variables in equation (4c) is reported in Table 7. As it can be seen from the result of this table, the null hypothesis of no short-run causality is rejected for all cases. It means that a short-run Granger causality runs from real GDP, energy consumption, and labor force to energy consumption in MENA.

Table 7. Short run causality when Δ LK is dependent variable

Dependent Variable Δ LK	F-statistic	Causality direction
$H_0: \alpha_{3j} = 0, \quad j = 1,2$	94.26071[a]	LY⟹LK
$H_0: \beta_{3j} = 0, \quad j = 1,2$	50.91297[a]	LE⟹LK
$H_0: \theta_{3j} = 0, \quad j = 1,2$	680.7340[a]	LL⟹LK

[a] indicates statistical significance at the 1% level or less.

Finally, we use the estimation result of equation (4d) (the last column of Table 4) to examine the causality when LL is dependent variable. The result of Wald test is reported in Table 8. It indicate that the null hypotheses: $H_0: \alpha_{4j} = 0,, H_0: \beta_{4j} = 0, H_0: \theta_{4j} = 0$, $j = 1{,}2$, are rejected. It hence confirms the presence of a short-run causality running from real GDP, investment and energy consumption to labor force.

Table 8. Short run causality when Δ LL is dependent variable

Dependent Variable Δ LL	F-statistic	Causality direction
$H_0: \alpha_{4j} = 0, \quad j = 1,2$	929.9320[a]	LY⟹LL
$H_0: \beta_{4j} = 0, \quad j = 1,2$	547.5323[a]	LE⟹LL
$H_0: \gamma_{4j} = 0, \quad j = 1,2$	54.61077[a]	LK⟹LL

[a] indicates statistical significance at the 1% level or less.

To sum up, the results of Granger causality tests (Tables 5-8) show that there is a short-run bilateral causal relationship between each pair of real GDP, energy consumption, real fixed capital formation, and the labor force.

The estimated coefficients of error correction terms (ECTs) are used to examine the presence of long-run causality. As it can be seen from Table 4, the coefficients of error correction terms, ECT(-1) are statistically significant. It hence confirms the existence of a long-run causal relationship between the variables.

Hence, the Granger causality test results support the existence of a bidirectional short- and long-run causal relationship between real output and energy consumption. On the basis of the short-run and long-run energy-GDP dynamics, we prove the feedback hypothesis. Our result verifies the findings of Huang et al. (2008), Apergis and Payne (2010b, 2010c), and Ozturk et al. (2010). The presence of bidirectional causality indicates that there is mutual interdependence between the variables under consideration in the MENA countries. More specifically, the result suggests that limiting energy use through energy conservation policy would slow down economic growth in this region.

Moreover, our results indicate that there is a bilateral causal relationship between real fixed capital formation and real GDP and between labor force and real GDP in MENA countries. In addition, we find out that real fixed capital formation Granger causes labor force and labor force in turn Granger causes fixed capital formation in both the short and long run. These results support the findings of Apergis and Payne (2009, 2010c) for six Central American countries and twenty OECD countries.

Given the existence of bilateral Granger causality between these variables, any policy that changes the energy consumption, real fixed capital formation and the labor force will finally change real GDP. Moreover, it emphasizes the important role of output growth in predicting energy consumption, investment and employment. In other words, a feedback effect exists between real GDP and its main determinants.

In order to find the long-run elasticities, we estimate two long-run equations. First, we estimate equation (3) in which LY is treated as dependent variable and LE, LK and LL are set to be explanatory variables. Next, we estimate equation (5) in which LE is dependent variable and LY, LK and LL are treated as independent variables.

$LE_{it} = \delta_0 + \delta_1 LY_{it} + \delta_2 LK_{it} + \delta_3 LL_{it} + v_{it}$, i=1,…,N and t=1,…,T. (5)

In which v_{it} is the disturbance term and δ_j is a parameter. The Generalized Method of Moment (GMM) is used to estimate the long run equations. The estimation results of equations (3) and (5) are reported in Table (9). Since the variables are in logarithm, the coefficients are interpreted as elasticity.

Table 9. The GMM estimation of long-run elasticity

Dependent Variable	Intercept	LY	LE	LK	LL
LY	10.32	-	0.38[a]	0.22[a]	0.36[a]
LE	-12.03[a]	0.60[a]	-	0.06[a]	0.39[a]

[a] indicates statistical significance at the 1% level or less.

The first row of Table 9 presents the result of GMM estimation where LY is the dependent variable. According to this result, a one percent increase in energy consumption raises the real output by 0.38 percent. This means that energy is an important source of economic growth in MENA countries including Iran. This result is close to the findings of Lee and Chang (2008) for 16 Asian countries and Lee (2005) for 18 developing countries. The long-run elasticity of real output with respect to fixed capital formation is 0.22. Moreover, a one percent increase in employment raises the real output by 0.36 percent.

The second row of Table (9) indicates that when the dependent variable is LE, all coefficients are statistically significant. More specifically, it shows that a one percent increase in real GDP raises energy consumption by 0.60 percent. The long-run elasticity of energy consumption with respect to labour force is 0.39. However, a one percent increase in fixed capital formation only raises energy consumption by 0.06 percent.

4. Concluding Remarks

This paper uses a panel data Vector Error Correction Model (VECM) to investigate the relationship between real gross domestic product (GDP) and energy consumption in MENA countries over the period 1987-2008 within a multivariate framework. This model allows us to examine the short- and long-run causal relationship between energy consumption and output growth when we control for the presence of capital and labor inputs. Generalized Least Squares (GLS) method in the context of Seemingly Unrelated Regression (SUR) with fixed effects model is used to investigate the existence of causality between the variables.

The estimation result confirms the existence of a long-run equilibrium relationship among energy consumption, fixed capital formation, employment and real output in MENA. The panel Granger causality tests reveal that there is a short- and long-run bidirectional Granger causality between real GDP and its main determinants including energy consumption. Our result is similar to the findings of

Lee and Chang (2007) for a group of 22 developed countries, Mishra et al. (2009) for a panel of 9 Pacific Island countries, Ozturk et al. (2010) for middle income economies, Apergis and Payne (2010b) for a panel of 67 countries, Apergis and Payne (2010c) for a group of twenty OECD countries, and Eggoh et al. (2011) for a panel of 21 African countries.

The existence of bidirectional causal relationship between energy and real GDP in MENA suggests that energy consumption promotes economic growth and economic growth in turn affects energy consumption. Our finding hence confirms the feedback hypothesis. It means that energy consumption and real output are interdependent. Hence, a shock to either one of these variables affects the other. It implies that energy can be considered as a limiting factor to output growth in this important region. More importantly, as Apergis (2009, p.212) has pointed out "if this is the case an energy policy oriented toward improvements in energy consumption efficiency would not adversely affect real GDP". This might have an important policy implication for MENA countries including Iran.

Finally, the Generalized Method of Moments (GMM) is used to estimate the long-run elasticities. The results show that the elasticity of real GDP with respect to energy consumption is 0.38. This finding shows how important could be the effect of energy shortages on the growth of output in Iran and other MENA countries as a group. Moreover, a 1% increase in real GDP raises energy consumption by 0.60% in this region. These findings may have important policy implications for policymakers and researchers in MENA countries and also for international organizations. We might conclude that an energy policy that results in the improvements of energy efficiency not only helps to conserve energy consumption but also boosts the economic output in these countries.

References

Abosedra, S. and H. Baghestani (1989), “New Evidence on the Causal Relationship between United States Energy Consumption and Gross National Product”, *Journal of Energy and Development*, No. 14, pp. 285–292.

Adeniran, O. (2008), “Does Energy Consumption cause Economic Growth? An Empirical Evidence from Nigeria”, *Energy Policy*, No. 30, pp. 401-413.

Adjaye, J.A. (2000), “The Relationship between Energy Consumption, Energy Prices and Economic Growth: Time Series Evidence from Asian Developing Countries”, *Energy Economics*, No. 22, pp. 615-625.

Akarca, A. and T. Long (1980), “On the Relationship between Energy and GNP: a Reexamination”, *Journal of Energy Development*, No. 5, pp. 326-31.

Apergis, N. and J.E. Payne (2009), “Energy Consumption and Economic Growth in Central America: Evidence from a Panel Cointegration and Error Correction Model”, *Energy Economics*, No. 31, pp. 211-216.

Apergis, N. and J.E. Payne (2010a), “Energy Consumption and Economic Growth in South America: Evidence from a Panel Error Correction Model”, *Energy Economics*, No. 32, pp. 1421-1426.

Apergis, N. and J.E. Payne (2010b), “Natural Gas Consumption and Economic Growth: A Panel Investigation of 67 Countries”, *Applied Energy*, No. 87, pp. 2759-2763.

Apergis, N. and J.E. Payne (2010c), “Renewable Energy Consumption and Economic Growth: Evidence from a Panel of OECD Countries”, *Energy Policy*, No. 38, pp. 656-660.

Baltagi, B. (2005), *Econometric analysis of panel data*, John Wiley and Sons. LTD, Toronto.

Belloumi, M. (2009), “Energy Consumption and GDP in Tunisia, Cointegration and Causality Analysis”, *Energy Policy*, No. 37, pp. 2745-2753.

Cheng, B.S. (1995), “An Investigation of Cointegration and Causality between Energy Consumption and Economic Growt”, *The Journal of Energy and Development*, No. 21, pp. 73-87.

Cheng, B.S. and T.W. Lai (1997), “An Investigation of Cointegration and Causality between Energy Consumption and Economic Activity in Taiwan”, *Energy Economics*, No. 19, pp. 435-444.

Chiou-Wei, S., Z. Chen and Z. Zhu (2008), “Economic Growth and Energy Consumption Revisited-Evidence from Linear and Nonlinear Granger Causality”, *Energy Economics*, No. 30, pp. 3063-3076.

Eggoh, J.C., C. Bangake and C. Rault (2011), “Energy Consumption and Economic Growth Revisited in African Countries”, *Energy Policy*, No. 39, pp. 7408–7421.

Engle, R.E. and C.W.J. Granger (1987), “Cointegration and error-Correction, Representation, Estimation, and Testing”, *Econometrica*, No. 55, pp. 251-276.

Ghali, K.H. and M.I.T. El-Sakka (2004), “Energy Use and Output Growth in Canada, a Multivariate Cointegration Analysis”, *Energy Economics*, No. 26, pp. 225-238.

Granger, C.W.J. (1988), “Some Recent Developments in a Concept of Causality”, *Journal of Econometrics*, No. 39, pp. 199-211.

Hall, C. A. S., C. J. Cleveland and R. K. Kaufmann (1986), *Energy and Resource Quality: The Ecology of the Economic Process,* Wiley Interscience, New York.

Hsiao, C. (2003), *Analysis of panel data*, Cambridge University Press, Cambridge.

Huang, B., M. J. Hwang and C.W. Yang (2008), “Causal Relationship between Energy Consumption and GDP Growth Revisited: A Dynamic Panel Data Approach”, *Ecological Economics*, No. 67, pp. 41 -54.

Im, K.S., M.H. Pesaran and Y. Shin (2003), “Testing for unit Roots in Heterogeneous Panels”, *Journal of Econometrics*, No. 115, pp. 53-74.

Kao, C. (1999), “Spurious Regression and Residual-based Tests for Cointegration in Panel Data”, *Journal of Econometrics*, No. 90, pp. 1–44.

Kraft, J. and A. Kraft (1978), “On the Relationship between Energy and GNP”, *Journal of Energy and Development*, No. 3, pp. 401-403.

Lee, C.C. (2006), “The Causality Relationship between Energy Consumption and GDP in G-11 Countries Revisited”, *Energy Policy*, No. 34, pp. 1086-1093.

Lee, C.C. (2005), “Energy Consumption and GDP in Developing Countries: A Cointegrated Panel Analysi”, *Energy Economics*, No. 27, pp. 415-427.

Lee, C.C. and C.P. Chang (2007), “Energy Consumption and GDP Revisited: A panel Analysis of Developed and Developing Countries”, *Energy Economics*, No. 29, pp. 1206-1223.

Lee, C.C. and C.P. Chang (2008), “Energy Consumption and Economic Growth in Asian Economies: A more Comprehensive Analysis Using Panel Data”, *Resource and Energy Economics*, No. 30, pp. 50-65.

Lee, C.C. and M.S. Chien (2010), “Dynamic Modelling of Energy Consumption, Capital Stock, and Real Income in G-7 Countries”, *Energy Economics*, No. 32, pp. 564-581.

Lorde, T., K. Waithe and B. Francis (2010), “The Importance of Electrical Energy for Economic Growth in Barbados”, *Energy Economics*, pp. 1-10.

Masih, A. M. M. and R. Masih (1996), “Energy Consumption, Real Income and Temporal Causality: Results from a Multi-country Study based on Cointegration and Error-correction Modelling Techniques”, *Energy Economics*, No. 19, pp. 165-183.

Mehrara, M. (2007), “Energy Consumption and Economic Growth: The case of oil Exporting Countries”, *Energy Policy*, pp. 2939-2945.

Mishra, V., R. Smyth and S. Sharma (2009), “The Energy-GDP nexus, Evidence from a Panel of Pacific Island Countries”, *Resource and Energy Economics*, No. 31, pp. 210-220.

Narayan, P. K. and R. Smyth (2008), “Energy Consumption and Real GDP in G7 Countries: New Evidence from Panel Cointegration with Structural Breaks”, *Energy Economics*, No. 30, pp. 2331-2341.

Nondo, C. and M. Kahsai (2009), Energy consumption and economic growth, evidence from COMESA countries, Southern Agricultural Economics Association Annual Meeting, Atlanta, Georgia, 1-17.

Oh, W. and K. Lee (2004), “Causal Relationship between Energy Consumption and GDP Revisited the case of Korea 1970-199”, *Energy Economics*, No. 26, pp. 51-59.

Ozturk, I. (2010), “A literature survey on energy–growth nexus”, *Energy Policy*, No. 38, pp. 340–349.

Ozturk, I. and A. Acaravci (2011), “Electricity Consumption and Real GDP Causality nexus: Evidence from ARDL Bounds Testing Approach for 11 MENA Countries”, *Applied Energy*, No. 88, pp. 2885–2892.

Ozturk, I., A. Aslan and H. Kalyoncu (2010), “Energy Consumption and Economic Growth Relationship: Evidence from Panel Data for Low and Middle Income Countries”, *Energy Policy*, No. 38, pp. 4422-4428.

Payne, J.E. (2009), “On the Dynamics of Energy Consumption and Output in the US”, *Applied Energy*, No. 86, pp. 575-577.

Pedroni, P. (1999), “Critical Values for Cointegration Tests in Heterogeneous Panels with Multiple Regressors”, *Oxford Bulletin of Economics and Statistics*, No. 61, pp. 653–670.

Pedroni, P. (2004), “Panel Cointegration: Asymptotic and Finite Sample Properties of Pooled Time Series Tests with an Application to the PPP Hypothesis New Results”, *Econometric Theory*, No. 20, pp. 597–627.

Soytas, U. and R. Sari (2003), “Energy Consumption and GDP: Causality Relationship in G-7 Countries and Emerging Markets”, *Energy Economics*, No. 25, pp. 33-37.

Stern, D. I., (1999), “Is energy cost an accurate indicator of natural resource quality?”, *Ecological Economics*, No. 31, pp. 381-394.

Stern, D.I. (1993), “Energy Use and Economic Growth in the USA, a Multivariate Approach”, *Energy Economics*, No. 15, pp. 137-150.

Stern, D.I. (2000), “A Multivariate Cointegration Analysis of the Role of Energy in the US Macroeconomy”, *Energy Economics*, No. 22, pp. 267-283.

Word Bank (2003), MENA Development Report: Trade, Investment, and Development in the Middle East and North Africa Engaging with the World. Washington, D.C.

World Bank (2010), MENA Regional Economic Update: Recovering from the Crisis, April 2010.
http://web.worldbank.org/WBSITE/EXTERNAL/
COUNTRIES/MENAEXT/0,contentMDK:22577735~pagePK:146736~piPK:146830~theSitePK:256299,00.html.

Yang, H.Y. (2000), “A Note on the Causal Relationship between Energy and GDP in Taiwan”, *Energy Economics*, No. 22, pp. 309-317.

Yu, E.S.H. and J.Y. Choi (1985), “The Causal Relationship between Energy and GNP: An International Comparison”, *Journal of Energy and Development*, No. 10, pp. 249-272.

Yu, E.S.H. and B. Hwang (1984), “The Relationship between Energy and GNP, Further Results”, *Energy Economics*, No. 6, pp. 186-190.

Zamani, M. (2007), “Energy Consumption and Economic Activities in Iran”, *Energy Economics*, No. 29, pp. 1135-1140.