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An Analysis of the Relationship between Electric Power Consumption and Economic Growth in D8 Countries

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ABSTRACT: In today's world, achieving the highest economic growth possible is an issue which has drawn much attention on the part of both economists and politicians especially in the developing countries. Energy as one of the most important factors in production, alongside with workforce and capital, plays a significant role in enhancing production and economic growth. Among all alternative energy forms and energy carriers, electricity enjoys the highest diversity of use, Minimizing the costs of energy consumption in industry leads to economic growth and development. Moreover, due to its natural effectiveness, and cleanness and lower pollution rate, as well as easy transmission, electricity has always been sought for the world over. However, this popularity brings along some basic questions. For instance, can electricity consumption induce more production and economic growth in developing countries? Or does economic growth in itself entail a boost in electricity consumption? To address these questions, this study aims at analyzing this relationship in the D8 group in the 1971-2010 interval using Pooled Mean Group Estimation of Dynamic Heterogeneous Panels (PMGE). The results show a mutual relationship between electricity consumption and economic growth. In other words, in D8 countries, electricity consumption and economic growth interact and complement each other.

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INTRODUCTION

Economic growth is a process centered on the growth of gross domestic product. Development planning aims at preparing national resources and facilities for a higher production of necessary commodities and services. However, the attempt for more and better production, in addition to the enhancement in production factors, should utilize more vastly and more intensively all the resources including human resources, capital, and energy resources; in other words, when the growth rate soars significantly, there will be an escalating pressure on the resources. Hence, there will be a rise in demand for specialized workforce, as well as the need for capital, capital equipment and consumption of raw material and energy. Therefore, if there is not the opportunity to utilize any of the above-mentioned resources along with the production growth, production will suffer.

Production, whether industrial or agricultural, is not possible without infrastructures such as electricity. Nowadays, regarding the new improvements in industry such as transforming the mechanical energy into the electric energy, emergence of electric engines, expansion of machine tools, as well as lower pollution among energy carriers, electric power plays a major role in development and economic growth. As a result, the relationship between economic growth and electricity consumption as a major factor in production has drawn much attention on the part of the economic analysts.

Theoretical bases

Achieving a high rate of economic growth as one of the most significant economic indicators is an issue that has always attracted both economists' and politicians' attention. Noticeably, energy plays an effective role in increasing domestic product (Mehrara *et al*, 2011). In the next part, there will be a review of economic viewpoints regarding this issue.

Economic Viewpoints on Energy Consumption and Economic Growth

Nowadays, energy is regarded one of the most significant factors affecting the economic growth. During the past decades, various view shave been put forward on how energy affects production and economic growth. These views can be divided into two

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general groups of "views of ecological economists" and "views of neoclassic economists". The ecological economists consider energy as the dominant variable in production function and factors like workforce and capital as intermediate ones. Stern (2004) are among economists advocating this viewpoint. In the other campaign, the neoclassic economists believe that energy has a minor role in economic growth and production and is only an intermediate variable overshadowed by capital, workforce, and land.

In fact, in neoclassic theory of growth, the focus is on the substituting or complementary property of energy with regard to other production factors as well as on the interrelation between energy, technical developments, and productivity using functions of total or partial production or general balance approaches.

To study the link between growth and energy consumption the growth theory can be viewed in two categories: classic school and neoclassic school. The classic economists have not evidently considered energy as a production factor. They sought the growth constrains in land. Due to the economic structure back then, the classic theories were generally focused on land and agriculture. Following the industrial revolution, few economists have taken into account the consumption of other energy carriers in limiting the growth and revenue (ShahidAlam, 2006).

Relationship between Domestic Product and Energy Consumption

According to various economic schools, the most important factors affecting the economic growth in growth functions have been capital and workforce.

Nowadays, however, in addition to variables of labor and capital, energy is also taken into consideration as an important variable in macroeconomics literature. Therefore, production is a function of variables of labor, capital, and energy (Maleki, 2002):

$$Q= f(K, L, E) \quad (1)$$

where Q is the domestic gross product, K is capital, L is workforce, and E is variable of energy which can be provided for through items such as oil, gas, electricity, coal, etc known as energy carriers. Also it is presumed that there is a direct relationship between the consumption rates of these variables and production levels. Mathematically:

$$\frac{\partial Q}{\partial K} > 0 \text{ و } \frac{\partial Q}{\partial L} > 0 \text{ و } \frac{\partial Q}{\partial E} > 0 \quad (2)$$

That is, the increase in energy consumption leads to the increase in production and economic growth. On the other hand, Pindike (1979).Believes that the effect of energy costs on economic growth depends on the role of energy in the production structure. He suggests that in industries where energy is used as an intermediate variable in production, the increase in energy costs (that is the decrease in its consumption) affects the facilities as well as rates of production hence decreases the national product. He uses the total cost function to show his theory basing his analysis on elasticity production cost in relation to energy cost:

$$C = C(P_k, P_l, P_E, Q) \quad (3)$$

Where,P_E, P_l, and, P_k are respectively energy cost, workforce cost, and capital, and Q is the production amount. He uses the Trans log cost functions to get the cost elasticity of production in relation to energy cost:

$$\frac{d\ln C}{d\ln P_E} = S_E + S_k \times \eta_{kE} \times \frac{\partial \ln P_k}{\partial \ln K} + S_l \times \eta_{lE} \times \frac{\partial \ln P_l}{\partial \ln L} \quad (4)$$

where $\frac{d\ln C}{d\ln P_E}$ is elasticity of total cost in relation to energy cost, S_l and S_k are the effects of an increase in respectively workforce and capital on the cost (the elasticity of total cost in relation to the cost of workforce and capital), and η_{kE} and η_{lE} are price cross-elasticity of capital and workforce.

The trinomial at the right side of (4) shows the impact on the economy of a shock induced by energy cost. The first expression shows the direct effect of energy cost and indicates that costs increase with the boost in energy cost which in turn leads to a decrease in production. The second and third expressions point at the indirect impacts of energy cost. Whenever there are substitute relations between energy on the one hand and capital and workforce on the other, the fluctuation in energy cost can have indirect effects on the cost and eventually on the product through substituting other variables for energy (Pindike, 1979).

Generally, most of authorities consider the relationship between labor and capital in normal situations as a substitution one; however, in the short run, since the production structure is unable to react to the cost increase, energy will be complementary with capital and labor. Therefore, in the short run, due to cross elasticity of labor and capital being negative in relation to energy cost, the indirect effects of the change in the energy cost are parallel to the direct effects, which amplify these effects.

If capital and labor are considered as substitutes of energy, the increase in energy cost leads to the increase in the use of capital and labor, which makes the proportional quotient of production based on these two factors increase. This way, the increase in energy cost will change the allocation of production factors. In the long run, this seems logical, because industries in the long run will change their structure with the energy becoming more expensive, trying to minimize the use of other more expensive variables. Brandt and Wood have put forward another theory. They reason that in the total production function, there is one production factor which has a weak separable relationship with labor. Their suggested production function is expressed as

$$Q = f\{G(K,E),L\} \quad (5)$$

This function means energy and capital are combined together forming the production factor G. When this is combined with labor, there will be product. Therefore, labor is only combined with G, and not individually with either capital or labor. Therefore, the function points to the fact that the energy consumption will affect the final production of capital without affecting the final production of labor.

The Causal Routes between Energy Consumption and Growth

Regarding the studies over the past thirty years, the causal relationship between energy consumption and economic growth can be divided into four diverse hypotheses. Growth hypotheses suggest that energy consumption has a positive effect on the economic growth, acting as a complement for workforce and capital. In other words, if the increase in energy consumption is the cause of increase in economic growth, these hypotheses are confirmed. Second, the conservation hypotheses hypothesize that energy consumption is independent from economic growth, if only the one way causality from growth to energy consumption exists. Third, feedback hypothesis highlights the mutual relationship between energy consumption and economic growth.

Feedback hypotheses have been proved through the existence of mutual causality between energy consumption and economic growth. Fourth, neutrality hypothesis indicates that energy consumption has a proportionally slight role in economic growth (Apergis and Payne, 2009).

Methodology: Pooled Mean Group Estimation of Dynamic Heterogeneous Panels

In recent years, there has been a great interest in dynamic data model which analyzes the observations on cross-section data during several periods. These models are specially used in cross- country analyses. Generally, two methods are used for estimating such dynamic heterogeneous panels. Pesaran and Smith (1995) and Pesaran et al.(1999) showed that it is possible to calculate the coefficients of the model through calculating the mean of regressions separately for each period of panel data, or through integrating parameters of the model and estimating the model like a system. They called the first method Pooled Mean Group Estimation and the second method Mean Group Estimation. According to Asterio et al. (2002) and Pesaran et al.(1999) it is possible to write a Auto Regressive Distributed Lag model for t= 1,2,...T and i= 1,2,...N in the following way:

$$y_{it} = \sum_{j=1}^{p} \lambda_{ij} y_{i,t-j} + \sum_{j=0}^{q} \delta'_{ij} x_{i,t-j} + \mu_i + \varepsilon_{it} \quad (6)$$

Where t is the period, i is the interval, y_{it} is the vector (k x 1) from the dependent variable for the i[th] group, $x_{i,t}$ is the vector (K x 1) from explanatory variables for i[th] group, p and q are the numbers of intervals of respectively dependent and explanatory variables, μ fix expressions of eachlag ,λ_{ij} the coefficients of the variables dependent on scholar form and δ'_{ij} the vector (k x 1) of estimation coefficients, and ε_{it} are residual. It should be noted, however, that in practice each panel could be imbalanced, and p and q could be different for different intervals. Also, T should be big enough to be able to estimate each equation separately for each interval or group.

Equation (6) for i= 1,2...N and t=1,2...Tcould be changed into a vector error correction model (VECM):

$$\Delta y_{it} = \emptyset_i y_{i,t-1} + \beta'_i x_{i,t} + \sum_{j=1}^{p-1} \lambda^*_{ij} \Delta y_{i,t-j} + \sum_{j=0}^{q-1} \delta^{*\prime}_{ij} \Delta x_{i,t-j} + \mu_i + \varepsilon_{it} \quad (7)$$

So that for t periods and i intervals after converting (3-1) to a VECM and reaching (3-2) respectively, the coefficients of VECM will be calculated as follows:

$\phi_i$is the dependent lagvariable coefficient $y_{i,t-1}$, and is equal to $\phi_i = -(1 - \sum_{j=1}^{p} \lambda_{ij})$

$\beta_i$is the long-run coefficient ofthe explanatory variable $x_{i,t}$, and is equal to $\beta_i = \sum_{j=0}^{q} \delta_{ij}$

δ^*_{ij} are indicative of coefficients of dependent differential lagvariables$\Delta y_{i,t-j}$ for q−1 intervals, and λ^*_{ij}

shows the coefficients of explanatory differential lag variables$\Delta x_{i,t-j}$ for p−1 intervals which indicate the long-run causality between the explanatory and dependent variables, and are equal toand

$$\delta^*_{ij} = -\sum_{m=j+1}^{q} \delta_{ij} \quad ,j = 1,2,\dots,q-1$$

and

$$\lambda_{ij}^{*} = -\sum_{m=j+1}^{p} \lambda_{im}, j = 1,2,\dots,p-1$$

If the observations of time series for each group are accumulated, (3-2) will be changed like the following:

$$\Delta y_i = \emptyset_i y_{i,-1} + \beta_i x_i + \sum_{j=1}^{p-1} \lambda_{ij}^{*} \Delta y_{i,-j} + \sum_{j=0}^{q-1} \delta_{ij}^{*} \Delta x_{i,-j} + \mu_i \iota + \varepsilon_{it}$$

(8)

where for i=1,2...N, $y_i = (y_i 1{,}000, y_{iT})'$ is the vector $(T \times 1)$ of observations of the dependent variable of i[th] group, $x_i = (x_i 1{,}000, x_{iT})'$ is the matrix $(T \times K)$ of explanatory variables, $\iota = (1, \dots 1)$ is vector $(T \times 1)$ of one, and $y_{i,-j}$ and $x_{i,-j}$ are the values of j[th]lag of y_i and x_i, and $\Delta y_i = y_i - y_{i,-1}$, $\Delta x_i = x_i - x_{i,-1}$, $\Delta y_{i,-j}$and$\Delta x_{i,-j}$ is the value of the j[th]lag from Δy_i and Δx_i, $\varepsilon_i = (\varepsilon_{i1}, \dots, \varepsilon_{iT})'$ is the vector $(T \times 1)$ of the error expressions. Also, coefficients of δ_{ij}^{*} indicate that there is a long term causality between explanatory variables and dependent variables. The estimator of integrated group mean provides thatβ's for the same intervals are calculated. Moreover, Pesranet al. (1999) have suggested maximum likelihood estimation method for this relationship. Therefore, likelihood functions are determined after posing the coefficients and are estimated like a system of simultaneous equations (Pesaranet al., 1999).

specification the Model

As was discussed earlier, this model provides the possibility of analyzing and estimating long term coefficients and Causal relationship between dependent and explanatory variables. therefore, according to the framework of regression model of pooled mean group estimation of dynamic heterogeneous panels, the specification form of the model is as follows:

$$\Delta lnGDP_{it} = \alpha_{1i} + \theta_{1i} lnGDP_{i-1} + \beta_{1i} lnEC_i + \sum_p \varphi_{11ip} \Delta lnGDP_{it-p} + \sum_p \varphi_{12ip} \Delta lnEC_{itp-1} + \psi_{1i} ECM_{t-1} + \varepsilon_{it} \quad (9)$$

$$\Delta lnEC_{it} = \alpha_{2i} + \theta_{2i} lnEC_{i-1} + \beta_{2i} lnGDP_i + \sum_p \varphi_{21ip} \Delta lnEC_{it-p} + \sum_p \varphi_{22ip} \Delta lnGDP_{itp-1} + \psi_{2i} ECM_{t-1} + \varepsilon_{it} \quad (10)$$

So that:

EC is the annual power consumption per capita in kwh;

GPD is real gross domestic product per capita, And ECM is the speed of short term modification to long term.

The specified data for all D8 countries including Iran, Turkey, Bangladesh, Malaysia, Indonesia, Nigeria, Pakistan, and Egypt are extracted annually for the period 1971-2010 through world development index (WDI) and were collected by World Bank.

The estimations of this study were done through software like Eviews and RATS.

After estimating the equations (9) and (10), in order to analyze the causality between the variables and its direction, the tests $H_0 = \varphi_{12ip} = 0$ and $H_0 = \varphi_{22ip} = 0$ are carried out for causality in the above equations so that the rejection of null hypothesis in (9) is indicative of a causal relationship from electricity consumption toward economic growth; and the rejection of null hypothesis in (10) is indicates that economic growth is the cause of electricity consumption (Ozturk et al., 2010).

Estimating the Model

5-1- Panel data unit root test

In this study, unit root tests based on panel data, Im, peasant, shin (IPS)(2003) and Fischer's test have been used. In this study, the null hypothesis is the existence of unit root. As seen in table 1, it could be concluded that all variables will be stationary after a Difference times and therefore all the variables are the integration 1 or I(1) which , provides the prerequisite for conducting the integration tests for analyzing relationships between variables.

Table 1. Results of unit root test of panel data of variables.

Test	variable	symbol-statistics	probability	t-statistics probability		
IPS:	Electricity consumption	EC	2.188	0.985	-6.250	0.000
	Gross domestic product	GDP	2.527	0.944	-5.555	0.000
Fischer ADF:	Electricity consumption	EC	2.253	0.987	-5.697	0.000
	Gross domestic product	GDP	2.274	0.988	-5.204	0.000
Fischer ADF:	Electricity consumption	EC	1.215	0.888	-16.613	0.000
	Gross domestic product	GDP	3.745	0.999	-9.421	0.000

Source: research findings

Cointegration test of panel data

Regarding the fact that based on the results of unit root test of panel data it was confirmed that the variables are integrated of order one or I (1), in the next step the existence of long term balance relationships between the variables is tested. This relationship is analyzed by Pedroni (2004)integration test (1999-2004). Table 3 contains the results of Pedroni (2004) integration test.

Table 3. Pedroni (2004) integration test (1999-2004)

Statistic type	statistic name integration statistics for Electricity Consumption and Economic growth
Within dimension Test statistics:	
Panel v-statistic	1.262(0.179)
Panel rho-statistic	-1.601(0.110)
Panel pp-statistic	-6.637(0.000)
Panel ADF-statistic	-11.897(0.000)
Between dimension Test statistics:	
Group rho-statistic	0.289(0.382)
Group pp-statistic	-4.579(0.000)
Group ADF statistic	-7.495(0.000)

Source: research findings

The numbers in parentheses indicate the probability of the calculated statistic of the test at 95 % signification

As can be seen, based on the results above , integration or a long term relationship between electricity consumption and economic growth is confirmed by between dimension Test statistics and within dimension Test statistics.

results of estimation and causality of PMGE

In this part, the results of estimation and causality of PMGE related to analyzing the causal relationship between electricity consumption and economic growth and electricity consumption based on specification of the suggested model according to equations (9) and (10) are completely shown.

These indicate the coefficients of the long term and causal relationship between electricity consumption and economic growth. Also the coefficients of causality test of panel data are separately given in table 4:

Table 4. Results of causality test of panel data.

Direction of causality	Coefficient	ECMt-1
$\Delta \ln y \rightarrow \Delta \text{Ln } ec$	0.512(0.000)	-1.143(0.048)
$\Delta \ln ec \rightarrow \Delta \ln y$	0.596(0.000)	-1.574(0.038)

The numbers in parentheses show the probability of calculated statistic at 5% signification.

According to the results of table4, there is a long term causal relationship from economic growth to electricity consumption in D8 countries. Furthermore, based on these results, there is a long term causal relationship from energy consumption to economic growth. In general, it is evident that there is a mutual causal relationship between energy consumption and economic growth in D8 countries.

DISCUSSION

The results of the present study indicate that economic growth in D8 countries affects the energy consumption. In other words, the conservation hypothesis (one way causal relationship from economic growth to energy consumption) is confirmed in these countries. Therefore, the policy of energy conservation has not had a constructive effect on economic growth, and the improvement in economic growth in these countries in the above-mentioned period has led to a constant increase in electricity consumption; in other words, economic growth has caused electricity consumption. On the other hand, according to the results, there is a long term causal relationship from electricity consumption to economic growth which indicates growth hypothesis is confirmed in D8 countries. In fact, electricity consumption has had a positive effect on economic growth and has been considered as a complement for capital and labor.

Overall, it is evident that there is a mutual causal relationship between electricity consumption and economic growth in D8 countries, that is, the feedback hypothesis is confirmed in these countries, which means each positive/negative shock on electricity provision has positive/negative effects on the economy.

Based on the experimental findings of the research, it is possible to reason that increasing the electricity consumption will lead to a growth in economic sectors. On the other hand, the growth of different economic sectors in D8 countries will lead to an increase in electricity consumption. Therefore, the significance of effective planning for providing economic sectors with their electricity demands in order to achieve economic growth and development is evident. Moreover, the constrain policies which are implemented with the aim of optimizing the economy of a country can be used in D8 countries without posing any obstacle to the economic growth.

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