AES BIOFLUX
Advances in Environmental Sciences - International Journal of the Bioflux Society

The relationship between energy consumption and economic growth in Iran: dynamic causality test

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Abstract. Energy consumption, as an important output factor, can play an effective role in economic growth of each country. Hence, studying the relevance of energy consumption and economic growth has a significant importance. Investigating this relationship would greatly help in setting up each country's energy efficiency strategies. In the upcoming research, the relationship between energy consumption and economic growth has been studied using trivariate demand side and trivariate plus four-variate supply side models. Auto Regressive Distribute Lag (ARDL)-Bounds test is the applied method throughout this research. It will concentrate on short run and long run relationships between energy consumption and macroeconomic variables during 1971-2009 period. Results show that there is a unidirectional causal relationship from energy consumption to economic growth in both short and long run. In the demand side, it was noticed that there is long run relationship between energy consumption, economic growth and energy price. Considering energy price in this study, the unidirectional causal relationship between energy consumption and economic growth changed to a bidirectional causal relationship. In trivariate supply side, there is noticed a long run relationship between energy consumption, economic growth and labor force. The causal relation between energy consumption and economic growth is a bidirectional relationship in trivariate supply side. There is also a bidirectional relationship between labor force and energy consumption and between economic growth and labor force. In four-variate model, there has been noticed a bidirectional causal relationship between energy consumption and economic growth, labor force and capital, labor force and energy consumption, labor force and economic growth and finally between capital and economic growth.
Key Words: use of energy, GDP, ARDL-Bounds test, dynamic causality.

Introduction. Energy as an important factor in production plays an important role alongside with other factors in countries' economic survival and its importance is increasing day by day. Increasing dependency of human life on energy leads to the fact that this sector plays vital role potentially and practically in countries' economic. From different economic schools' point of view, effective factors on economic growth which are included in growth functions are capital and labor such as expert and non-expert, and in new growth patterns the energy factor is inserted. But its importance in different models is not uniform (Stern 1993). Energy cost affects the demand for energy; therefore it can affect the relationship between economic growth and energy consumption. On the other hand if we consider the sectors included in production the capital and labor, it may be possible that in some cases the capital and labor would replace the energy, thus the 2 mentioned sectors can influence the relationship between economic growth and energy consumption (Maleki 2005). Recognizing the effective factors on the relationship between energy consumption and growth can be helpful to find more accurate answers and are perfect directories for making suitable policies. The causality between economic growth and energy consumption is ambiguous and this is different based on the country's economic construction. Understanding these relationships would provide valuable policy insight into particularly when practicing the policies related to preserving energy sources (Bartleet & Gounder 2010). The most important factors that cause to do this research is the importance of energy and economic growth in Iran, this country not only has rich source of energy, but aslo achieve positive economic growth is one of the main targets.

Thus, changes in energy price and the removal of fuel subsidy create much concern about negative effect on key economic variables, especially on economic growth. In this article the long-term relationship between economic growth and energy consumption and also the long and short-term causality relationship between the mentioned variables in tri-variable models of demand, supply and 4 variables are evaluated. Due to finding the accurate answers and modifying the results obtained from 2-variables model the tri- and 4 variables models of demand, supply are used. To evaluate them, the Auto Regressive Distribute Lag (ARDL) and annual statistics of economy of Iran during 1971-2009 are used.

In production sector before industrial revolution the economy emphasized on two factors of working and capital. Emerging the industrial revolution and changing the production process, raw materials are also added to major factors of production and are considered in economic evaluations. Both before and after industrial revolution of the important factors in production, whether natural or physical, was energy which due to its abundance has been considered less by economists, because one of the main features of sources and factors of production which are studied in economy is being scarce which is seen less in energy. But from 1970s, after the increase of raw oil cost and emergence of economic crisis the energy issue and its scarce was addressed and is considered extensively by economists especially in industrial countries and energy is particularly studied in economic literatures as a scarce source and production functions has placed the energy in their studies. In fact, in new theories of growth the energy is added to the model (Stern & Cleveland 2004).

From different economic schools point of view, the role of energy consumption in production function and economic growth is different. In biophysical model of growth, the energy is the only and most important factor of growth because based on the first principle of thermodynamic; energy is fixed in nature, compensable and can be changed to material and never terminated. So produced goods in economy, even trained and non-expert labor resulted by consumption of energy in large scale and are used in production. The value becomes good in economy explicitly is due to the applied energy source from nature (Ayres & Knees 1969). Then in biophysical model which is pioneered by ecological economists such as Ayres & Nair (1984), the energy is the main and the only factor of production and capital and labor are mediatory factors which need energy to be used. In fact they believe that energy consumption leads to economic growth. One of the most important studies of biophysical models by Cleveland et al (1984) evaluates the close relationship between energy consumption and Gross Domestic Production (GDP). Neoclassicists economists like Berndt (1978) and Denison (1979) are opposite to ecological economists. Neoclassicists believe that energy affects indirectly the economic growth by the effect it has on labor and capital and is not directly effective. They believe that demand for energy is a derivative demand and economic growth leads to energy consumption. Most of the neoclassicist economists believe in a principle that energy plays a small role in economic production and is a mediatory sector and the main factors of production are labor and land. Pindyck (1979) believed that the effect of cost of energy on economic growth depends on the energy role in production construction. To his opinion in industries in which energy is mediatory sector in production, increasing its cost (reduction of energy consumption) would affect the amount of production and facilities and decreases the national production. He uses the total costs function to show that and analyze based on the production costs elasticity to energy cost. If capital and labor are considered as alternatives for energy, then the increase of cost of energy leads to increase of the two factors and increase of production costs due to increase of cost of energy changes the production factors allocation and would increase the relative share of production caused by the labor and capital.

Odhiambo (2008) using ARDL approach during 1971-2006 concluded that in South Africa and Kenya the unilateral causality relationship is from energy consumption to economic growth. Also, in Kenya there is long-term relationship from cost of energy to economic growth and short-term causality relationship from energy consumption to cost of energy and in Congo there is long-term causality relationship from energy

consumption to cost of energy and short-term causality relationship from cost of energy to economic growth.

Herrerias et al (2013) analyzed the relationship between energy consumption and economic growth in different regions of China using the Panel method. The results indicated a unidirectional causal relationship from economic growth to energy consumption in the long term.

Ocal & Aslan (2013) investigated the causal relationship between renewable energy consumption and economic growth in Turkey. The results of ARDL method showed a negative unidirectional causal relationship from renewable energy consumption to economic growth. Also, the results of Toda-Yamamoto method showed a unidirectional causal relationship from economic growth to renewable energy consumption.

Lin & Moubarak (2014) examined the relationship between renewable energy consumption and economic growth in China using ARDL method. The results indicated a bidirectional causal relationship between renewable energy consumption and economic growth in the long term and unidirectional causal relationship from work force to energy consumption in the short term.

Shahbaz et al (2014) examined the relationship between natural gas consumption and economic growth in the short term and long term in Pakistan using ARDL method. The results indicated a unidirectional relationship from gas consumption to economic growth and causality tests suggested bidirectional causality between these two variables.

Park & Yoo (2014) investigated the relationship between oil consumption and economic growth using Granger causality in Malaysia. The results indicated a bidirectional causal relationship between oil consumption and economic growth.

Material and Method. The ARDL pattern can evaluate the long and short term coefficients and determines the causality between variables and also eliminates the problems related to deletion of self-correlation variable. In this method unlike other ones such as Granger-angle there is no need to information of accumulation of mentioned variables in analysis of the accumulation (Pesaran & Pesaran 1997; Pesaran 1997; Pesaran & Shin 1998).

Also, due to the fact that the models typically are free of problems such as sequential self-correlation and endogenity, the obtained estimations are relevant and non-diagonal. This research evaluates the relationship between energy consumption and production growth using variables like energy consumption, real gross production, cost of energy, labor and net fixed capital in tri-variable model of demand and supply and 4 variables. Bound-test are used to evaluate the co-integration.

The following models are used:

In bi-variable model of energy consumption and economic growth:

$$\Delta Ln\ GDP_t = \vartheta_0 + \sum_{i=1}^{n} \vartheta_1 \Delta Ln\ EC_{t-i} + + \sum_{i=1}^{n} \vartheta_2 \Delta LnGDP_{t-i} + \vartheta_3 LnGDP_{t-1} + \vartheta_4 LnEC_{t-1} + \Pi_{1t} \quad (1)$$

$$\Delta Ln\ EC_t = \psi_0 + \sum_{i=1}^{n} \psi_1 \Delta Ln\ EC_{t-i} + + \sum_{i=1}^{n} \psi_2 \Delta LnGDP_{t-i} + \psi_3 LnGDP_{t-1} + \psi_4 LnEC_{t-1} + \Pi_{2t} \quad (2)$$

Where LnGDP is normal logarithm of GDP and LnEC is natural logarithm of total energy consumption.

In demand side:

$$\Delta Ln\ GDP_t = \lambda_0 + \sum_{i=1}^{n} \lambda_1 \Delta Ln\ EC_{t-i} + \sum_{i=1}^{n} \lambda_2 \Delta Ln\ EP_{t-i} + \sum_{i=1}^{n} \lambda_3 \Delta LnGDP_{t-i} + \lambda_4 LnGDP_{t-1} + \lambda_5 LnEC_{t-1} + \lambda_6 LnEP_{t-1} + \varepsilon_{1t} \quad (3)$$

$$\Delta Ln\ EC_t = \theta_0 + \sum_{i=1}^{n} \theta_1 \Delta Ln\ EC_{t-i} + \sum_{i=1}^{n} \theta_2 \Delta Ln\ EP_{t-i} + \sum_{i=1}^{n} \theta_3 \Delta LnGDP_{t-i} + \theta_4 LnGDP_{t-1} + \theta_5 LnEC_{t-1} + \theta_6 LnEP_{t-1} + \varepsilon_{2t} \quad (4)$$

$$\Delta Ln\ EP_t = \gamma_0 + \sum_{i=1}^{n} \gamma_1 \Delta Ln\ EC_{t-i} + \sum_{i=1}^{n} \gamma_2 \Delta Ln\ EP_{t-i} + \sum_{i=1}^{n} \gamma_3 \Delta LnGDP_{t-i} + \gamma_4 LnGDP_{t-1} + \gamma_5 LnEC_{t-1} + \gamma_6 LnEP_{t-1} + \varepsilon_{3t} \quad (5)$$

LnEP = normal logarithm of energu price

In supply side:

in tri-variable function of supply:

$$\Delta Ln\ GDP_t = \alpha_0 + \sum_{i=1}^{n} \alpha_1 \Delta Ln\ EC_{t-i} + \sum_{i=1}^{n} \alpha_2 \Delta Ln\ L_{t-i} + \sum_{i=1}^{n} \alpha_3 \Delta LnGDP_{t-i} + \alpha_4 LnGDP_{t-1} + \alpha_5 LnEC_{t-1} + \alpha_6 LnL_{t-1} + \mu_{1t} \quad (6)$$

$$\Delta Ln\ EC_t = \chi_0 + \sum_{i=1}^{n} \chi_1 \Delta Ln\ EC_{t-i} + \sum_{i=1}^{n} \chi_2 \Delta Ln\ L_{t-i} + \sum_{i=1}^{n} \chi_3 \Delta LnGDP_{t-i} + \chi_4 LnGDP_{t-1} + \chi_5 LnEC_{t-1} + \chi_6 LnL_{t-1} + \mu_{2t} \quad (7)$$

$$\Delta Ln\ L_t = \pi_0 + \sum_{i=1}^{n} \pi_1 \Delta Ln\ EC_{t-i} + \sum_{i=1}^{n} \pi_2 \Delta Ln\ L_{t-i} + \sum_{i=1}^{n} \pi_3 \Delta LnGDP_{t-i} + \pi_4 LnGDP_{t-1} + \pi_5 LnEC_{t-1} + \pi_6 LnL_{t-1} + \mu_{3t} \quad (8)$$

L= total labor

In 4 variable function of supply:

$$\Delta LnGDP_t = \beta_0 + \sum_{i=1}^{n} \beta_1 \Delta LnEC_{t-i} + \sum_{i=1}^{n} \beta_2 \Delta LnL_{t-i} + \sum_{i=1}^{n} \beta_3 \Delta LnGDP_{t-i} + \sum_{i-1}^{n} \beta_4 \Delta LnK_{t-i} + \beta_5 LnGDP_{t-1} + \beta_6 LnEC_{t-1} + \beta_7 LnL_{t-1} + \beta_8 LnK_{t-1} + \omega_{1t} \quad (9)$$

$$\Delta LnEC_t = \varphi_0 + \sum_{i=1}^{n} \varphi_1 \Delta LnEC_{t-i} + \sum_{i=1}^{n} \varphi_2 \Delta LnL_{t-i} + \sum_{i=1}^{n} \varphi_3 \Delta LnGDP_{t-i} + \sum_{i-1}^{n} \varphi_4 \Delta LnK_{t-i} + \varphi_5 LnGDP_{t-1} + \varphi_6 LnEC_{t-1} + \varphi_7 LnL_{t-1} + \varphi_8 LnK_{t-1} + \omega_{2t} \quad (10)$$

$$\Delta LnL_t = \phi_0 + \sum_{i=1}^{n} \phi_1 \Delta LnEC_{t-i} + \sum_{i=1}^{n} \phi_2 \Delta LnL_{t-i} + \sum_{i=1}^{n} \phi_3 \Delta LnGDP_{t-i} + \sum_{i-1}^{n} \phi_4 \Delta LnK_{t-i} + \phi_5 LnGDP_{t-1} + \phi_6 LnEC_{t-1} + \phi_7 LnL_{t-1} + \phi_8 LnK_{t-1} + \omega_{3t} \quad (11)$$

$$\Delta LnK_t = \delta_0 + \sum_{i=1}^{n} \delta_1 \Delta LnEC_{t-i} + \sum_{i=1}^{n} \delta_2 \Delta LnL_{t-i} + \sum_{i=1}^{n} \delta_3 \Delta LnGDP_{t-i} + \sum_{i-1}^{n} \delta_4 \Delta LnK_{t-i} + \delta_5 LnGDP_{t-1} + \delta_6 LnEC_{t-1} + \delta_7 LnL_{t-1} + \delta_8 LnK_{t-1} + \omega_{4t} \quad (12)$$

Where K is pure fixed capital.

After evaluation, the null hypothesis $= \vartheta_4 = \vartheta_3$: H_0 which means the inexistence of long-term relationship against the $\neq \vartheta_4 \neq \vartheta_3$: H_1 which means the existence of long-term relationship are examined. If the computational statistics F would be out of critical region then H_0 is rejected. In present research to examine the causality the granger's causality test using the Vector Error Correction Model (VECM) is used. The causality test is as follow:

The causality test in bi-variable of energy consumption and economic growth:

$$\Delta Ln\ GDP_t = \Omega_{10} + \sum_{i=1}^{n} \Lambda_{1i} \Delta Ln\ GDP_{t-i} + \sum_{i=1}^{n} \varsigma_{1i} \Delta Ln\ EC_{t-i} + \varpi_{11} ECT_{t-1} + \upsilon_{1t} \quad (13)$$

$$\Delta Ln\ EC_t = \Omega_{20} + \sum_{i=1}^{n} \Lambda_{2i} \Delta Ln\ GDP_{t-i} + \sum_{i=1}^{n} \varsigma_{2i} \Delta Ln\ EC_{t-i} + \varpi_{21} ECT_{t-1} + \upsilon_{2t} \quad (14)$$

The causality test in demand side:

$$\Delta Ln\ GDP_t = \alpha_{10} + \sum_{i=1}^{n} \beta_{1i} \Delta Ln\ GDP_{t-i} + \sum_{i=1}^{n} \gamma_{1i} \Delta Ln\ EC_{t-i} + \sum_{i=1}^{n} \delta_{1t} \Delta Ln\ EP_{t-i} + \varphi_{11} ECT_{t-1} + \eta_{1t} \quad (15)$$

$$\Delta Ln\ EC_t = \alpha_{20} + \sum_{i=1}^{n} \beta_{2i} \Delta Ln\ GDP_{t-i} + \sum_{i=1}^{n} \gamma_{2i} \Delta Ln\ EC_{t-i} + \sum_{i=1}^{n} \delta_{2t} \Delta Ln\ EP_{t-i} + \varphi_{21} ECT_{t-1} + \eta_{2t} \quad (16)$$

$$\Delta Ln\ EP_t = \alpha_{30} + \sum_{i=1}^{n} \beta_{3i} \Delta Ln\ GDP_{t-i} + \sum_{i=1}^{n} \gamma_{3t} \Delta Ln\ EC_{t-i} + \sum_{i=1}^{n} \delta_{3t} \Delta Ln\ EP_{t-i} + \varphi_{31} ECT_{t-1} + \eta_{3t} \quad (17)$$

The Granger's causality test in tri-variable model of supply:

$$\Delta Ln\ GDP_t = \hat{\alpha}_{10} + \sum_{i=1}^{n} \hat{\beta}_{1i} \Delta Ln\ GDP_{t-i} + \sum_{i=1}^{n} \hat{\gamma}_{1t} \Delta Ln\ EC_{t-i} + \sum_{i=1}^{n} \hat{\delta}_{1t} \Delta Ln\ L_{t-i} + \hat{\varphi}_{11} ECT_{t-1} + \tau_{1t} \quad (18)$$

$$\Delta Ln\ EC_t = \hat{\alpha}_{20} + \sum_{i=1}^{n} \hat{\beta}_{2i} \Delta Ln\ GDP_{t-i} + \sum_{i=1}^{n} \hat{\gamma}_{2t} \Delta Ln\ EC_{t-i} + \sum_{i=1}^{n} \hat{\delta}_{2t} \Delta Ln\ L_{t-i} + \hat{\varphi}_{21} ECT_{t-1} + \tau_{2t} \quad (19)$$

$$\Delta Ln\ L_t = \hat{\alpha}_{30} + \sum_{i=1}^{n} \hat{\beta}_{3i} \Delta Ln\ GDP_{t-i} + \sum_{i=1}^{n} \hat{\gamma}_{3t} \Delta Ln\ EC_{t-i} + \sum_{i=1}^{n} \hat{\delta}_{3t} \Delta Ln\ L_{t-i} + \hat{\varphi}_{31} ECT_{t-1} + \tau_{3t} \quad (20)$$

The Granger's causality test in 4-variable model of supply:

$$\Delta Ln\ GDP_t = \alpha'_{10} + \sum_{i=1}^{n} \beta'_{1i} \Delta Ln\ GDP_{t-i} + \sum_{i=1}^{n} \gamma'_{1i} \Delta Ln\ EC_{t-i} + \sum_{i=1}^{n} \delta'_{1t} \Delta Ln\ L_{t-i} +$$

$$\sum_{i=1}^{n} \theta_{1i} \Delta Ln\, K_{t-1} + \varphi'_{11} ECT_{t-1} + \mu_{1t} \qquad (21)$$

$$\Delta Ln\ EC_t = \alpha'_{20} + \sum_{i=1}^{n} \beta'_{2i} \Delta Ln\ GDP_{t-i} + \sum_{i=1}^{n} \gamma'_{2i} \Delta Ln\ EC_{t-i} + \sum_{i=1}^{n} \delta'_{2t} \Delta Ln\ L_{t-i} +$$

$$\sum_{i=1}^{n} \theta_{2i} \Delta Ln\, K_{t-1} + \varphi'_{21} ECT_{t-1} + \mu_{2t} \qquad (22)$$

$$\Delta Ln\ L_t = \alpha'_{30} + \sum_{i=1}^{n} \beta'_{3i} \Delta Ln\ GDP_{t-i} + \sum_{i=1}^{n} \gamma'_{3i} \Delta Ln\ EC_{t-i} + \sum_{i=1}^{n} \delta'_{3t} \Delta Ln\ L_{t-i} +$$

$$\sum_{i=1}^{n} \theta_{3i} \Delta Ln\, K_{t-1} + \varphi'_{31} ECT_{t-1} + \mu_{3t} \qquad (23)$$

$$\Delta Ln\ K_t = \alpha'_{40} + \sum_{i=1}^{n} \beta'_{4i} \Delta Ln\ GDP_{t-i} + \sum_{i=1}^{n} \gamma'_{4i} \Delta Ln\ EC_{t-i} + \sum_{i=1}^{n} \delta'_{4t} \Delta Ln\ L_{t-i} +$$

$$\sum_{i=1}^{n} \theta_{4i} \Delta Ln\, K_{t-1} + \varphi'_{41} ECT_{t-1} + \mu_{4t} \qquad (24)$$

The number of optimal lags for each of the variables is determined using the Akaiek and Schwartz Bysian criterion. Granger's short term causality relationship using the statistics F depends on each of the variables of the examinations and the speed of adaptation in long-term is obtained using coefficient ECT.

Results and Discussion. In this section we first examine the inertia. If the variable is I (2) the value of F is not reliable. To evaluate the variables from inertia point of view the extended Dike Fuller test is used whose results state that variables like normal logarithm of total energy consumption and working are in inert level. Therefore the variables are I (0). Variables like normal logarithm of GDP, cost of energy and pure fixed capital due to the load of subtraction become the inert, then are I (1). Generally, the co-integration economy concept states a balanced relationship in long-term between 2 or more time series. Range test is a new method to evaluate and investigate the existence or inexistence of the long term relationship between variables. One of the co-integration methods is using the co-integration test of Pesaran et al (2001). This test is to determine the existence or inexistence of long term relationship between variables levels regardless of the fact that regressions are absolutely I(0), absolute I(1) or cross co-integration. To do the tests, first the infinite error correction model is evaluated. In test of the range the length of optimal lag is computed based on the Schwarz Baysian Criterion. If computational statistics F is more than upper bound of Pesaran et al (2001), then the null hypothesis of inexistence of long term relationship would be rejected and if lower than the lower bound then the null hypothesis is not rejected and if the mentioned F is between the 2 bounds, then there is no result of the existence or inexistence of the long term relationship. If the existence of long term relationship between variables is confirmed, using ADRL method the long and short term relationship between variables would be determined. To estimate using ADRL maximum optimal lags of the model using Schwartz Baysian Criterion (SBC) would be selected for each variable individually. Therefore the long term relationship between variables are obtained and interpreted. In the following part the interruption component of long term vector and short term are estimated using VECM and then using the component of VEC it would be obvious that if there is a shock in long term vector is it going to be balanced or not. All of the above mentioned stages are examined for variables of tri- and 4- variables models of demand and supply. The results of range test explains the balanced relationship between GDP and

energy consumption as well as energy consumption and GDP, on one hand in model of GDP and energy consumption the lag is three and energy consumption and GDP optimal lag is one. After the test and making sure of the existence of long term relationship between GDP and energy consumption estimated long term vector and its results are presented in Table 1.

Table 1

Results of long term estimation using ARDL between economic growth and energy consumption, GDP is dependent variable - the ARDL (1-1) is selected

Statistics t	*Coefficient*	*Variable*
3.0975	1.2299	(LNEC)
4.56298	4.3445	(C)

Evaluating the long term vectors from Table 1, the following results are obtained. According to long term vector of logarithm of energy consumption, following the increase of GDP the energy consumption increases; therefore due to increase of GDP of one percent, the energy consumption would increase about 0.46 percent. In other word when productions in one country increase, energy consumption would increase there but in amount fewer than the increase of production. According with long term vector of logarithm of GDP, following the increase of energy consumption increases the GDP about 1.2 percent. Also when energy consumption increases shows that in economic sectors there are more goods being produced that energy consumption has increased. Due to the con-integration relationship between a set of variables one can use VECM which relates the short term variables values to their balanced long term values. In this equation related to energy consumption the coefficient of error correction is 0.045 which shows that each year 0.045 of the unbalanced energy consumption is being balanced. The coefficient of error correction id equation of GDP is 0.058 and each year 0.058 of the unbalances is being balanced. Based on the short term logarithmic vector for energy consumption, increase in GDP leads to increase of energy consumption. Therefore in short term when GDP increases the energy consumption increases as well. Based on the short term logarithmic vector for GDP, increase in energy consumption leads to increase of GDP. Therefore results of the short term and long term vectors are the same and more energy consumption leads to more GDP.

The results of the range test between variables of tri-variables of demand state that there is long term relationship between sets of variables like GDP, energy consumption and cost of energy. On one hand model of GDP, energy consumption as well as cost of energy accepts lag 1 and optimal lag 1 respectively. After testing and making sure of the fact that there is long term relationship between variables, estimated long term vector and its results are presented in Table 2.

Table 2

Results of long term estimation using ARDL between variable demands, the cost is dependent variable, the ARDL (1, 0, 0) is selected

Statistics t	*Coefficient*	*Variable*
2.0352	1.3780	(LNGDP)
3.5445	0.40277	(LNEC)
-1.2974	-10.6274	(C)

Evaluating the long term vectors from Table 2, the following results are obtained. According to long term vector of logarithm of energy consumption, following the increase of GDP the energy consumption increases; therefore due to increase of GDP of one percent, the energy consumption would increase about 0.8 percent. In other word when productions in one country increase, energy consumption would increase there and it is economically accepted too. Also due to the increase in cost of energy about 1 percent

energy consumption decreases about 0.49 percent which shows the rule of demand for energy that if the cost increases then demand would decrease.

According to long term vector of logarithm of GDP, following the increase of energy consumption the GDP increases; therefore due to increase of energy consumption of one percent, the GDP would increase about 0.8 percent. It is economically accepted that energy is one of the production factors. Therefore the more production is, more need to energy would be. Also due to the increase in cost of energy about 1 percent energy consumption decreases about 0.65 percent because based on economic theories increase of energy cost reduces the demand and consumption and following this the production would be reduced. According with long term vector of logarithm of energy consumption, following the increase of GDP the energy consumption increases; therefore due to increase of GDP of one percent, the energy consumption would increase about 1.3 percent. In other word when productions in one country increase, energy consumption would increase there because energy supply doesn't increase as rapid as the demand does, so the cost of energy would increase. Also due to the increase in energy consumption about 1 percent energy price increases about 0.4 percent because increase in good consumption increases the demand for that and then it would affect the price and energy price would increase. Due to the con-integration relationship between a set of variables one can use VECM which relates the short term variables values to their balanced long term values. Considering the Table 2 the ECM (-1) is meaningful. In equation related to energy consumption the VECM = -0.06 which shows that each year 0.067 of the unbalance in energy consumption become balanced. The VECM in equation of GDP is -0.16 which means that each year 0.16 of unbalance become balanced. The VECM for energy consumption equals to -0.13 and each year 0.13 of unbalance become balanced.

According to short term vector of logarithm of energy consumption, following the increase of GDP the energy consumption increases; because increase of production leads to energy consumption increase. Therefore in line with increase of production energy consumption would increase. Also due to the increase of energy price, energy consumption would decrease because increase in energy price reduces the demand for energy based on the rule of demand. According to short term vector of logarithm of GDP, following the increase of energy consumption the GDP increases; because increase of energy consumption leads to production increase. Therefore in line with increase of energy price the GDP would be reduced because increase in energy price reduces the demand for energy and following that reduces the productions. According to short term vector of logarithm of energy consumption, following the increase of GDP the energy consumption increases; because increase of production leads to energy consumption increase and if the demand for energy is increasing the cost is increasing accordingly. Therefore in line with increase of energy consumption the energy price would increase because increase in energy consumption increases and then the price of energy would increase.

The results of the range test between variables of tri-variables of demand state that there is long term relationship between sets of variables like GDP, energy consumption and labor. On one hand model of GDP, energy consumption as well as cost of energy accepts lag 1 and optimal lag 2 respectively. The estimated long term vector and its results are presented in Table 3.

Table 3

Results of long term estimation using ARDL between variable demands, the labor is dependent variable, the ARDL (2, 0, 0) is selected

Statistics t	*Coefficient*	*Variable*
5.4746	0.29229	(LNGDP)
3.0797	0.46075	(LNEC)
1.3167	10.9468	(C)

Evaluating the long term vectors from Table 3, the following results are obtained. According to long term vector of logarithm of energy consumption, following the increase

of GDP the energy consumption increases. Therefore due to one percent increase in GDP, the energy consumption increases about 0.12 percent because increase of production leads to energy consumption increase which increases the demand for energy. Also due to the increase of labor only one percent, energy consumption would increase 1.3 percent because labor is a factor of production, then increase in labor increases the production and then more energy would be needed. Thus energy consumption would increase. According to long term vector of logarithm of GDP, following the increase of energy consumption the GDP increases; therefore due to one percent increase in GDP, the energy consumption increases about 2.2 percent. Because increase of energy consumption leads to production increase. Also due to the increase of labor only one percent, energy consumption would increase 6.3 percent because labor is a factor of production, then increase in labor increases the production. According to long term vector of logarithm of labor, following the increase of GDP the labor increases. Therefore due to one percent increase in GDP, the energy consumption increases about 0.29 percent because increase of production leads to labor increase because more production needs more factors of production. Thus following the increase of production labor would be increasing. Also due to the increase of energy consumption only one percent, energy consumption would increase 0.46 percent because increase of energy consumption leads to increase of production and for more production more labor would be needed.

Due to the con-integration relationship between a set of variables one can use VECM which relates the short term variables values to their balanced long term values. In ECM equation related to energy consumption coefficient of error correction equals to -0.09 which shows that each year 0.09 of unbalanced energy consumption is balanced. The coefficient of error correction for GDP equals to -0.14 and means that each year 0.14 of unbalance becomes balanced. The coefficient of error correction for labor equals to -0.028 and means that each year 0.028 of unbalance becomes balanced.

According to short term vector of logarithm of energy consumption, following the increase of GDP the energy consumption increases; because increase of production leads to increase of needed energy consumption. Therefore energy consumption would increase. Also due to the increase of labor, energy consumption would increases because increase in labor increases the production therefore there is more requirement for energy and energy consumption would be increasing. According to short term vector of logarithm of GDP, following the increase of energy consumption the GDP increases; because to produce new goods energy is used. Also due to increase of labor, the GDP increases. The more labor working, more production would occur. According to short term vector of logarithm of labor, following the increase of GDP the labor increases. In line with increase of production, the need for labor increases therefore the labor would be increasing. Also increase of energy consumption the labor would increase because increase in energy consumption increases the production and then the labor would increase.

The results of the range test between variables of tri-variables of demand state that there is long term relationship between sets of variables like GDP, energy consumption and labor and capital. On one hand model of GDP, energy consumption as well as cost of energy accepts lag 1 and optimal lag 2 and capital accepts the lag 2, respectively. The estimated long term vector and its results are presented in Table 4.

Table 4

Results of long term estimation using ARDL between 4-variable of demand, the capital is dependent variable; the ARDL (2, 0, 1, 0) is selected

Statistics t	*Coefficient*	*Variable*
5.6091	2.1460	(LNGDP)
2.4283	1.8573	(LNEC)
-3.7037	-3.1122	(LNL)
-2.9793	-35.3839	(C)

According to long term vector of logarithm of energy consumption, following the increase of GDP the energy consumption increases; therefore due to increase of GDP of one

percent, the energy consumption would increase about 0.18 percent whose reason as mentioned earlier is that to produce more the more energy is needed. So energy consumption increases. Also due to the increase in labor about 1 percent energy consumption increases about 1.2 percent. Thus the more labor causes more production and therefore leads to more demand for energy and also due to increase of capital of 1 percent, energy consumption increases 1.4 percent. Therefore the more capital being used in economy lead to growth of production and energy consumption increases. According to long term vector of logarithm of GDP, following the increase of energy consumption the GDP increases; therefore due to increase of energy consumption of one percent, the GDP would increase about 0.29 percent which shows that energy is one of the production factors that increase of its consumption leads to increase of production. Also due to the increase of labor of about 1 percent, the GDP increases about 1.4 percent. Therefore labor also is one of the production factors and when it is increasing, the production increases too and also 1 percent increase in capital leads to 0.26 percent increase of GDP. Capital also is the production factor and following its increase the production increases. According to long term vector of logarithm of labor, following the increase of GDP the labor increases; therefore due to increase of GDP of one percent, the labor would increase about 0.8 percent. When production is increasing the demand for more labor is more. Therefore the labor would increase. Also due to the increase in energy consumption about 1 percent the labor increases about 0.6 percent. Thus the more energy consumption causes more production and therefore leads to more demand for labor and also due to increase of capital of 1 percent, labor decreases 0.2 percent because labor and capital are interchangeable. Therefore when the capital increases there is less demand for labor.

Based on the long term logarithm of capital, following the increase of GDP, the capital increases too; therefore due to the increase of 1 percent in GDP, the capital increases 2.1 percent. Because to produce more there is more demand for need for capital and so the capital increases. Also due to the increase of energy consumption one percent the capital increases 1.8 percent. Because energy and capital are complementary factors in production then in line with energy consumption increase, more capital would be consumed to increase the production and also due to the increase of labor one percent, capital decreases 3 percent.

As mentioned earlier capital and labor are two interchangeable factors, so when the labor increases the capital is decreasing. According to the existence of co-integration relationship between set of variables one can use VECM to relate the short term values to their long term balanced ones. In equation ECM (-1) related to the energy consumption coefficient of vector error correction equals to -0.37 and shows that each year 0.37 of unbalanced energy consumption is being balanced. Coefficient of VECM in equation of GDP is -0.36 and means that each year 0.36 of unbalance is being balanced. Coefficient of VECM of labor is -0.23 and means that each year 0.23 unbalance trend can be balanced. Coefficient of VEC of capital is -0.63 and means that each year 0.63 unbalance trend can be balanced.

Based on the short term logarithm of energy consumption following the increase of GDP, the energy consumption increases because to produce more, there is more need to energy. Also due to increase of labor the energy consumption would increase because labor and energy are complementary in production and increase in labor leads to increase of energy consumption to increase the production and also due to increase of capital the energy consumption increases, because energy and capital are complementary too and increase in capital leads to more energy for more production.

Based on the short term logarithm of GDP following the increase of energy consumption the GDP increases because energy consumption is a production factor whose increase leads to increase of production. Also due to the increase of labor the GDP also increases because labor is a production factor and when it is increasing the production increases accordingly. Due to increase in capital energy consumption increases too. In this case in line with increase of capital because it is production factor, production increases too.

According to the short term logarithm of labor following the increase of GDP, then labor increases. Because to produce more there is requirement for more labor. Also due to increase of energy consumption, there is increase in labor. Because energy consumption and labor are complementary factors for production and increase in one leads to increase of the other so that the production increases and also due to increase of capital one percent, the labor decreases because these are interchangeable and increase of one leads to decrease of the other.

Based on the long term logarithm of capital following the increase of GDP, capital increases too; because capital is a production factor and is needed for more production. Also due to increase of energy consumption, the capital increase too. Because energy and capital are complementary and also due to increase of labor the capital decreases and confirms that both capital and labor are interchangeable.

After estimation of vector of variables for 3-variable model of demand and 3 and 4-variable model of supply we focus on the results of causality tests. If H_0 about the zero coefficients in each causality test is rejected, therefore bilateral causality exists between variables. If one is rejected and the other is accepted the causality is unilateral and if both are accepted shows that there is no causality relationship between variables. In the present study to do causality tests the granger's causality test using VECM is used. Based on the causality test on short term VECM the following results are obtained. The results related to economic growth and energy consumption show that there is causality from energy consumption to economic growth in short term and on one hand there is not causality from economic growth to energy consumption in short term. Thus related to economic growth and energy consumption the causality is unilateral from energy to economic growth. It means that in short term the more energy consumption changes, more change the production will have. This is compatible with ecologists' theories that energy consumption leads to economic growth. The results obtained from economic growth and energy consumption in 3-variable model of demand show that the causality is from energy consumption to economic growth in short term. Also there is causality from economic growth to energy consumption in short term. Then related to economic growth and energy consumption in 3-variable model of demand the causality is bilateral and means that in short term the more energy changes, more production will change and the change of growth leads to change of energy consumption. In this case we can say that insertion of energy price makes the unilateral relationship to bilateral causality one. We can say that in short term the energy price is an important factor and the manufacturer when want to change his/her production regarding the energy price, changes the energy consumption and so due to the energy price the causality relationship becomes bilateral.

Considering the economic growth and energy consumption in 3-variable model of demand we concluded that causality is from energy consumption to economic growth and on one hand causality is from economic growth to energy consumption in short term. It means that causality is bilateral between these variables. Considering the relationship between energy consumption and energy price also the mentioned relationship exists meaning that in short term the more energy price change leads to change of economic growth and energy consumption increases; vice versa. Results of relationship between economic growth and energy consumption in 3-variablee function show that causality is from energy consumption to economic growth in short term. Also there is causality from economic growth to energy consumption in short term. Therefore related to economic growth and energy consumption in 3-variable supply the causality is bilateral. It means that in short term the more energy consumption leads to more changes in production and also causes the change in energy consumption. Related to insertion of labor, relative to economic growth and energy consumption, the unilateral causality changes to bilateral one and we can say that in short term the labor is an important factor and when manufacturer changes his/her production considering the labor, changes the energy consumption too and therefore in presence of labor the causality would be bilateral.

Regarding the economic growth and energy consumption in 3-variable function of supply also the results show that the causality is from labor to economic growth and from economic growth to labor in short term. It means that the causality relationship is bilateral. Considering the relationship between labor and energy consumption the

mentioned relationship is observed and means that there is bilateral causality between energy consumption and labor. Therefore in short term the more labor changes, more production and energy consumption change; vice versa. The results of the relationship between economic growth and energy consumption in 4-variables function of supply show that the causality is from energy consumption to economic growth in short term as well as the presence of causality from economic growth to energy consumption short term. Therefore in relationship between economic growth and energy consumption in 4-variable model of supply the causality relationship is bilateral and means that in short term the more energy consumption leads to more production. Also changes in growth causes change in energy consumption. In this case insertion of labor and capital relative to economic growth and energy consumption changes the unilateral causality to bilateral relationship. One can say that in short term capital and labors are important factors and when manufacturer changes his/her production regarding the labor and capital the energy consumption changes too.

Due to the presence of labor the causality relationship becomes bilateral. Also in relationship between economic growth and energy consumption in 4-variable of supply the results show that there is a bilateral causality between capital and economic growth and also there is a bilateral causality between economic growth and labor in short term. On the other hand, there bilateral causality between capital and energy consumption and also energy consumption and labor in short term. Also there is bilateral causality between labor and capital in short term.

Regarding the results obtained from short term causality about hypotheses we can point to the followings:

- in short term, there is a unilateral causality from energy consumption to economic growth in Iran. Therefore the first hypothesis is confirmed;
- the energy price affects the causality relationship between energy consumption and economic growth and the second hypothesis is confirmed;
- the labor affects the causality relationship between energy consumption and economic growth and in presence of labor in short term the bilateral causality occurs between the variables and the third hypothesis is confirmed;
- labor and net fixed capital affect the causality relationship between energy consumption and economic growth and in presence of labor and capital in short term the bilateral causality occurs between the variables and the forth hypothesis is confirmed.

Based on the causality test of long term vector of VECM one can conclude that the results obtained from relationship between economic growth and energy consumption the results show that there is causality from energy consumption to economic growth in long term and on one hand, there is no causality relationship from economic growth to energy consumption. Then in relationship between economic growth and energy consumption causality is unilateral from energy to economic growth and means that in long term more energy consumption leads to more changes of production. The results of relationship between economic growth and energy consumption in 3-variable mode of demand show that the causality is from energy consumption to economic growth in long term and also is from economic growth to energy consumption in long term. Therefore in 3-variable model of demand the causality is bilateral relationship between economic growth and energy consumption and means that more energy consumption in long term leads to more change of production and economic growth and energy consumption. In this relationship insertion of energy price relative to the mentioned relationship the unilateral causality becomes a bilateral one. One can say that in long term energy price is an important factor and when manufacturer changes his/her production regarding the energy price, energy consumption is changed and so the causality becomes bilateral in presence of energy price. Considering the results of the 3-variable model of demand side the causality is from energy consumption to economic growth and on other hand the causality is from economic growth to energy price in long term. It means that there is bilateral causality relationship between these 2 variables. In relationship between energy consumption and energy price also the relationship is valid and means that in long term the more energy price change, more changes in economic growth and energy consumption occurs and vice versa. The results of the relationship between economic

growth and energy consumption in 3-variable function of supply show that causality is from energy consumption to economic growth in long term. Therefore in relationship between economic growth and energy consumption in 3-variable model of supply the causality is bilateral. It means that in long term the more energy consumed, more production occurs and also change of growth leads to change of energy consumption. In this relationship inserting the labor relative to economic growth and energy consumption the causality becomes bilateral.

In 3-variable function of supply the results obtained show that the causality is from labor to economic growth and also there is causality from economic growth to labor in long term and it means that there is a bilateral causality between the variables. In relationship between labor and energy consumption also the mentioned relationship is observed. Therefore there is bilateral relationship between energy consumption and labor and in long term the more labor changes, more production occurs and energy consumption increases more. The results of relationship between economic growth and energy consumption in 4-variable model of supply show that there is causality from energy consumption to economic growth in long term and there is causality from economic growth to energy consumption in long term. Therefore in relationship between the mentioned variables in 4-variable model of supply the causality is bilateral. It means that the more energy consumption leads to more change of production and growth changes leads to changes of energy consumption. In this relationship, inserting the labor and capital causes the change of causality from unilateral to bilateral relationship. In long term one can say that labor and capital are 2 main factors and when manufacturer changes the production regarding the labor and capital, he/she changes the energy consumption too and due to presence of labor the causality becomes bilateral. Also in relation with economic growth in 4-variable function of supply results obtained show that causality is bilateral between capital and economic growth and economic growth and labor in long term. On the other hand, there is bilateral causality between capital and energy consumption and labor and energy consumption. Also there is bilateral causality between labor and capital in long term.

Considering the results obtained from the long term causality, we can say about the hypotheses that:

- in long term, there is a unilateral causality from energy consumption to economic growth in Iran. Therefore the first hypothesis is confirmed;
- the energy price affects the causality relationship between energy consumption and economic growth in long term and the second hypothesis is confirmed;
- the labor affects the causality relationship between energy consumption and economic growth and in presence of labor in long term the bilateral causality occurs between the variables and the third hypothesis is confirmed;
- labor and net fixed capital affect the causality relationship between energy consumption and economic growth and in presence of labor and capital in long term the bilateral causality occurs between the variables and the forth hypothesis is confirmed.

Conclusions. This paper exposes the experimental finding of cointegration and causality between energy consumption and economic growth in Iran. Trivariate demand and multivariate supply models arrest attention, the importance of eliminiation of key variables. The results of bivariate model obtained from the article state that there are relationship between GDP and energy consumption in long term. The results of evaluating long and short term causality in relationship between economic growth and energy consumption show that there is unidirectional causality from energy consumption to economic growth. This finding is consistent with the ecological perspective.

Results of 3-variable model of demand in long term and short term there are relationship between all of variables include energy consumption, economic growth and energy price. Following the increase of GDP, energy consumption increases too and vice-versa, however, following the growth of energy price GDP and energy consumption decrease so there is inverse relationship from energy price to GDP and energy consumption. Results of evaluation of long and short term causality show the same result, and offer bidirectional relationship between energy consumption and GDP, energy

consumption and energy price, and also energy price and GDP. In fact, by entering of energy price variable in the equation, the one sided relationship between energy consumption and economic growth change to bilateral, that this result show the importance of energy price variable. One-sided relationship between energy consumption and GDP means that in short and long term more change in energy consumption leads to more change in production and also change in production changes the energy consumption. Energy price has the negative causality relationship with other variables, means more energy price leads to reduction in production and also energy consumption

Results of 3-variable model of supply show the relationship between energy consumption, GDP and labor in short and long term. Moreover, the bidirectional causality relationship is established between all of variables, include energy consumption and GDP, energy consumption and labor, and between GDP and labor. As can be seen, labor variable changed the unilateral causality relationship between energy consumption and GDP in bivariate model, to bidirectional causality relationship.

Results of 4-variable model of supply obtained relationship in long term and short term between energy consumption, GDP, labor and capital. The results of causality evaluation in short and long term show that in relationship between economic growth and energy consumption in 4-variable function of supply the causality is two-sided. One can say that in short term the labor and capital are effective factors and when manufacturer changes his/her production considering the capital and labor, in fact he/she changes the energy consumption. So due to presence of labor the causality becomes bilateral. Also results show that there is bilateral relationship between energy consumption and capital, and economic growth and capital in short and long term. On the other hand, it is observed that there is bidirectional causality relationship between labor and energy consumption. Also there is bilateral causality relationship between labor and capital in short and long term.

One of the aims of all developing countries nowadays is economic growth which considering the results of the present research to achieve it the following shames are suggested. According to this research the relationship between labor and capital are interchangeable; therefore, using more capital leads to lower use of labor and because in our country unemployment is a crisis now, then it is important for policy makers to pay attention to this important issue and try to use less capitals and program the use of more efficient industries and replace capital with labor to solve the problem of unemployment. On one hand, since there is complementary relationship between labor and energy, using more labor and following that more energy increases the economic growth. Based on findings of the article since increase in energy price leads to decrease of energy consumption and then production decreases and also due to the complementary relationship between capital and energy then using lower levels of energy due to elimination of subsidy and increase of energy price, using lower labor and less capital the economic growth decreases all of which lead to unemployment and reduction of production. Therefore it is necessary for policy makers to pay attention to these issues carefully and implement the planning more accurately.

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Received: 19 October 2014. Accepted: 25 April 2015. Published online: 01 May 2015.
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How to cite this article:
Mansouri S., 2015 The relationship between energy consumption and economic growth in Iran: dynamic causality test. AES Bioflux 7(3):324-337.