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## THE EFFECT OF ENERGY CONSUMPTION ON ECONOMIC GROWTH IN IRAN, A BAYESIAN ECONOMETRIC APPROACH

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### ABSTRACT

*The advent of severe fluctuations in energy price and environmental issues has made different countries in the world try to control energy consumption but the fear of the negative effect of controlling energy on economic growth has forced them to be more cautious in this case. Due to this, there are various studies about causal investigation between economic growth and energy consumption, followed by different results. Iran has rich and vast resources. The existence of huge underground reservoirs and potential energy, causes Iran to have a proper opportunity for using such energy resources. This study has sought to investigate the causal relationship between energy consumption and economic growth in Iran during 1965-2009 through Bayesian model averaging. The result of all three model fittings showed that economic growth of Iran, which has been assessed using Gross Domestic Production (GDP) growth in this study, is affected by energy consumption growth, human and labor factors, population growth and other factors such as import and export growth, inflation and the difference between the official and unofficial exchange rates. As a result, the research hypotheses, based on the effect of energy consumption and physical and human asset on economic growth was confirmed.*

**Keywords:** *Economic Growth, Energy Consumption, Bayesian Approach*

### INTRODUCTION

Energy is the driving force of any production activity and has a special place in economic growth and development. Nowadays, energy is widely used in the process of producing the required good and providing proper conditions of living. The increasing dependency on human life on energy consumption as a production factor increases economic growth (Shakibaei, 2002).

Although Iran is considered as one of the countries which provides the world energy and has rich energy savings, given the recent discussions over the control of energy consumption in Iran as well as targeted subscription, determining the relationship between energy consumption and production is of great importance. As a developing country with rich and vast energy resources and huge oil reservoirs, massive underground resources, and potential energy power, Iran is one of the growth models with pressure on natural resources (Barati Malayeri and Houri Jafari, 2008). Energy consumption is one of the economic growth components, on the other hand it can be one of the resources for creating pollution and ruining the environment. This subject is followed in economic literature in the form of the Kuznets curve (Mozayani and Moradhasel, 2014). Since 1970, after increasing crude oil prices and the advent of crisis in the world, the issue of energy and its scarcity was discussed and strongly drew the attention of economists, especially industrialized countries. The energy was particularly studied in economic researches

as a rare resource. Increasing these studies, a new branch of economy science, named energy economy, emerged, in which there are the functions of production and energy.

The form of production function before industrial revolution	$Q=f(1,k)$
Production function after industrial revolution	$Q=f(1,k,m)$
Production function after 1970s	$Q=f(1,k,m,E)$

The relationship between energy consumption and economic growth is an issue that has been noted in recent years in the field of economy. Moreover, the combination of energy consumption and the way of its allocation among different sections can be effective on the relationship between these variables.

## RESEARCH LITERATURE

Using the panel data approach, Lee and Chang (2008) studied the relationship between economic growth and energy consumption in 16 Asian countries during 1971-2002. They found out that there is no relationship between them in the short term while a one-way relationship from energy consumption to economic growth can be seen.

Ozturk, Aslan, and Kalyoncu, (2010), also investigated the relationship between energy consumption and economic growth in 51 low and average-income countries from 1971 to 2005. Their study shows that there is a one-way causal relationship from GDP to energy consumption in low-income countries. There is also a bilateral and, of course, a weak relationship between energy consumption and GDP in average-income countries.

Narayan and Smyth (2008) also showed that property, real GDP, and energy consumption in G7 countries are accumulated, assuming that property and energy consumption in the long term are the reasons for real GDP.

Yang, Hao-Yen, (2000) investigated the relationship between economic growth and consuming different types of energy such as oil, natural gas, and electricity in Taiwan from 1954 to 1997. The results of this study indicated a linear relationship between different types of energy consumption and economic growth. The politicians need to consider the way of each energy type effectiveness on economic growth nonlinearly to not to make mistakes in their decisions.

Apergis and Payne (2009) also investigated the relationship between energy consumption and economic growth in 6 countries of the Central American District from 1984 to 2004. This study shows that there is a long term balance between real national production, energy consumption, labor, and gross capital stock. It indicates that a 1% increase in energy consumption increases economic growth by 0.28%. 1% increase in gross capital stock and labor will be also followed by 0.18 and 0.61% of economic growth, respectively.

Abrishami Hamid and Azar Mostafaei (2002) investigated the relationship between GDP (or economic growth) and consuming major petroleum products (gasoline, kerosene, gas oil, and fuel oil). This study shows that there is a bilateral causal relationship between consuming major oil products and economic growth in the long term. In the short term, the results indicate a weak causal relationship from production to consuming major oil products.

Aziz Armen and Zare (2005) investigated the Granger causal relationship between energy consumption and economic growth from 1967 to 2002. The results of this study indicate a long term relationship between variables using a self-recursive method, proved in any mood.



Ghazi Amade and Abbasifar Hamid (2009) investigated causal relationships in the field of energy consumption. The obtained results showed a one-way short and long term causal relationship from final energy consumption and final electricity energy to economic growth. There is also a one-way short-term causal relationship from economic growth to the final consumption of natural gas.

Behboudi Davoud, Asgharpur Hossein, and Ghazvinian Mohammadhassan (2009) studied the relationship between energy consumption and economic growth using annual time-series data of Iran economy from 1967 to 2005, focusing on structural failure. The obtained result of this study shows that there is a positive long-term relationship between energy consumption and economic growth in Iran, considering structural failure.

Mehrara, Mohsen and Abrishami, Hamid and Sobhanian, Mohammad Hadi. (2012) Investigated the existence of a nonlinear relationship between economic growth and energy consumption growth in OPEC member countries and BRIC countries during 1980-2006 using threshold error correction model. Their results show that economic growth in both groups will be followed by an increase in energy consumption.

In a study of linear and nonlinear effects of energy consumption on the economic growth of Iran during 1959-2007 based on threshold regression approach, Mehrara, Mohsen and Zarei, Mahmoud. (2012) concluded that nonlinear models based on diagnostic statistics and coefficients significance present more satisfactory results than linear models in explaining the relationship between energy consumption and economic growth.

## RESEARCH METHODOLOGY

The basis of this study is the Bayesian econometrics approach and using its related methods. In this study, some effective variables on economic growth such as energy consumption growth, export growth, import growth, growth of gross investment, and growth of non-oil exports, margins of the exchange rate, and inflation and unemployment are first investigated. Then, using the Bayesian model, these variables in the economic growth of Iran were investigated. WALs averaging method, which is a balanced averaging method similar to Bayesian one, is used for better recognition of effective factors on final energy consumption. Moreover, the study data are time series and used statistical resources include Statistics available at the World Bank (WDI), the Central Bank (CBI), and energy balance sheets from 1967 to 2009.

The used variables of this study include GDP growth, energy consumption growth, energy price consumption, inflation rate, exports growth, imports growth, the growth of non-oil exports, the growth of the population, the growth of government revenues from the sale of oil and oil derivatives in current prices, the growth of money supply at current prices, the growth of liquidity at current prices, the growth of difference between the official and unofficial exchange logarithm, rate of unemployment and the growth of gross investment compared to GDP. GDP growth was considered as the dependent variable of the model and other ones as explanatory variables of the model.

## RESEARCH FINDINGS

### *Data Description*



Firstly, to identify the values of each variable, indicators of their concentration and distribution have been studied. The estimation of such indicators for study years has been proposed in Table 1.

**Table 1: Descriptive Findings of Research Variables**

Variable	Mean	Standard deviation	Minimum	Maximum
Energy price growth	-0.04420	0.12628	-0.40993	0.33296
GDP at a fixed price	0.04691	0.07070	-0.16410	0.16186
The inflation rate	15.68859	9.77751	0.00000	49.37392
Export growth	0.02515	0.24522	-1.08606	0.66190
Import growth	0.05151	0.21860	-0.44924	0.57681
Growth of non-oil exports	0.07161	0.41513	-0.71005	1.76417
Population growth	0.02383	0.00914	0.01109	0.03777
Growth of energy consumption	7.98429	5.92313	-6.72170	22.01863
Government revenue growth at current prices	0.19696	0.53372	-1.04801	2.22720
Money volume at current prices	0.20712	0.09934	-0.01927	0.47884
Liquidity at current prices	0.22550	0.07477	0.05847	0.45144
Logarithm of the difference between the official and unofficial exchange rates	0.81581	1.00023	0.00000	3.04978
Unemployment rate	12.00027	1.13828	9.72781	14.46047
Logarithm of gross investment to GDP ratio	-1.128407	0.195617	-1.50226	-0.62642

#### *Bayesian Mean Model*

BMA model has been fitted for explanatory variables of the study. The results of model fitting for this group of variables have been presented in Table 2.

**Table 2: BMA Model for Determining Effective Factors on GDP**

Variable	Impact factor	Standard deviation	t-statistics	Posterior probability
Fixed parameter	0.640159	1.151004	0.56	1
Time	-0.0004	0.0008	-0.47	0.29
Inflation rate	-0.0006	0.0008	-0.82	0.49
Export growth	0.1723	0.0308	5.60	1.00
Import growth	0.0994	0.0306	3.25	0.98
Growth of non-oil exports	-0.0113	0.0165	-0.68	0.40
Growth of energy consumption	0.0017	0.0018	0.93	0.56
Logarithm of the difference between the official and unofficial exchange rates	0.0020	0.0082	0.25	0.23

Unemployment rate	-0.0037	0.0061	-0.61	0.36
Population growth lag	-2.0231	1.4577	-1.39	0.85
Energy consumption growth lag	0.0016	0.0014	1.15	0.67

The fitted BMA model can be symbolized as follows:

$$GDP_i = 0.640 - 0.0004t - 0.0006Inflation_i + 0.172Export_i + 0.099Import_i - 0.011NO.Export_i + 0.0017EC_i + 0.002Log(Marginal_i) - 0.0037Unemployment_i - 2.023Population_{i-1} + 0.0016EC_{i-1}$$

The results of model fitting show that the export growth variable with the Bayesian impact factor of 0.172 and standard deviation of 0.030 has been considered in all fitted models and its posterior probability has been estimated as 1. It indicates the significant effect of this variable on GDP. Given its posterior probability, this variable has been the most effective among all model variables on GDP. Additionally, estimating the posterior probability of 0.98, there is adequate evidence for accepting the effectiveness of import-export growth on GDP as one of the second effective variable on GDP. The impact factor of this variable which is its posterior density function means it has been estimated as 0.099 with a standard deviation of 0.030. As can be seen, two variables of export and import growth are both effective on the increase of GDP significantly which are acceptable.

The first lag of the population with an impact factor of -2.023 and a standard deviation of 1.457 has the posterior probability of presence in the model equal to 0.85. There is strong evidence for confirming the negative effects of this variable on GDP. This coefficient shows that during the study years, population growth has had reverse and adverse effects on GDP. It shows non-compliance of GDP with population growth and inadequate timing of these two indicators.

Moreover, there is relatively strong evidence for confirming the effect of energy consumption growth effectiveness and its first lag on GDP. Energy consumption growth with an impact factor of 0.0017 and a standard deviation of 0.0018 positively affect GDP with a posterior probability of 0.56. Yet, the posterior probability of 0.67 for the lag of this index with a mean of 0.0016 and a standard deviation of 0.0014 shows that GDP is more affected by energy consumption growth of last year than the desired year. In other words, the higher the energy consumption in a year, given the impact factor of this index, the more will be the rate of GDP growth next year.

In the case of the inflation rate effect on GDP, we have to note that the posterior probability of this index is equal to 0.49. This value makes the researcher doubtful for rejecting this variable. Since the difference of posterior probability of this index is far lower than 50%, it has resulted that the annual inflation rate seems to be effective on GDP growth.

For other model variables such as time, non-oil export growth, unemployment rate, and the logarithm of difference between the official and unofficial rates of currency, there is not adequate evidence for accepting the effectiveness. Therefore, among study variables in BMA, these indicators are not significantly effective. It has to be noted that the claim does not mean absolute rejection of these variables' effectiveness on GDP growth but their effectiveness is not significant besides the mentioned indicators so they are not very important.

The extracted variables from the study process which have been significantly effective on GDP are ordered as follows given their posterior probability in the model (PIP) and their effect on GDP growth:



- 1- Export growth (+)
- 2- Import growth (+)
- 3- Population growth (-)
- 4- Energy consumption growth (+)
- 5- Inflation rate (-)
- 6- Non-oil export growth (-)
- 7- Unemployment rate (-)
- 8- Time (-)
- 9- The logarithm of difference between the official and unofficial rate of currency (+)

To compare research findings from estimations of the BMA model, the WALS model has been also proposed in Table 3 with explanatory variables.

**Table 3: WALS Model for Determining the Effective Factors on GDP**

Variable	Impact factor	Standard variation	t-statistics	The lower bound of 95%	The upper bound of 95%
Fixed parameter	2.20616	1.113728	1.98	1.092432	3.319887
Time	-0.00148	0.000795	-1.86	-0.00228	-0.00069
Inflation rate	-0.001	0.000513	-1.95	-0.00152	-0.00049
Export growth	0.144644	0.023808	6.08	0.120836	0.168451
Import growth	0.065154	0.021029	3.1	0.044125	0.086183
Growth of non-oil exports	-0.02157	0.012467	-1.73	-0.03404	-0.00911
Growth of energy consumption	0.002897	0.001157	2.5	0.00174	0.004055
Logarithm of the difference between the official and unofficial exchange rates	0.019001	0.009036	2.1	0.009965	0.028037
Unemployment rate	-0.00628	0.004808	-1.31	-0.01109	-0.00147
Population growth lag	-3.98133	1.252911	-3.18	-5.23424	-2.72842
Energy consumption growth lag	0.001389	0.000835	1.66	0.000553	0.002224

The fitted Weighted Average Least Square model (WALS) in this study can be symbolized as follows:

$$GDP_i = 2.206 - 0.0014t - 0.001Inflation_i + 0.144Export_i + 0.065Import_i - 0.021NO.Export_i + 0.0028EC_i + 0.019Log(Marginal_i) - 0.0063Unemployment_i - 3.981Population_{i-1} + 0.0013EC_{i-1}$$

Given that orthogonal linear and nonlinear combinations of variables are used in the WALS model, the estimated parameters in this model show the real effect of independent variables on dependent one so independent variables overlapping has been eliminated in the WALS model.

The results of this model, documenting to t-test statistics and their comparison with critical t value from t-student distribution table with one degree of freedom, almost 2, also shows that the indicators of export growth ( $t=6.08$ ), import growth ( $t=3.10$ ), population growth lag ( $t=-3.18$ ), energy consumption growth ( $t=2.5$ ) and the logarithm of the difference between the official and unofficial rate of currency ( $t=2.1$ ) are respectively effective on economic growth. Given the orthogonal effectiveness measurement in this model and information independency of independent variables to each other as well as the findings of the BMA model, it is claimed that fitted BMA model could well identify the effective variables on economic growth despite their intrinsic relations with other explanatory variables. Therefore, the compliance of their results with the results of the WALS model indicates its validity. In the case of the inflation rate variable ( $t=-1.95$ ), it is also seen than the value of this test statistic of this variable is near to the critical t value, confirming the obtained results from the BMA model.

**Table 4: Estimating the Coefficients of the Most Effective Variables in WALS and BMA Models**

Variable	WALS	BMA
Fixed parameter	2.20616	0.640159
Time	-0.00148	-0.0004
Inflation rate	-0.001	-0.0006
Export growth	0.144644	0.1723
Import growth	0.065154	0.0994
Growth of non-oil exports	-0.02157	-0.0113
Growth of energy consumption	0.002897	0.0017
Logarithm of the difference between the official and unofficial exchange rates	0.019001	0.0020
Unemployment rate	-0.00628	-0.0037
Population growth lag	-3.98133	-2.0231
Energy consumption growth lag	0.001389	0.0016

As the above Table shows, the coefficients of effective parameters in both models are estimated in one direction and near each other. It indicates the similarity of these methods' results. Yet, in this model, energy consumption growth lag does not affect GDP growth significantly while in BMA, the effectiveness of this index has been more than the effectiveness of energy consumption growth.

#### *OLS Model Estimation*

To determine the rate of model power in explaining the existing changes in GDP growth, the OLS model has been fitted using identified variables in BMA and WALS models. The results of fitting this model, done through classical statistics, have been proposed in Table 5.

**Table 5: OLS Model in Determining the Effective Factors on GDP**

Variable	Impact factor	Standard deviation	t-statistics	Significance level
Fixed parameter	2.665557	1.139951	2.34	0.026



Time	-0.00178	0.000815	-2.18	0.037
Inflation rate	-0.00125	0.000551	-2.27	0.031
Export growth	0.168666	0.025141	6.71	0
Import growth	0.075998	0.0234	3.25	0.003
Growth of non-oil exports	-0.02921	0.012624	-2.31	0.028
Growth of energy consumption	0.002753	0.001262	2.18	0.037
Logarithm of the difference between the official and unofficial exchange rates	0.025968	0.009238	2.81	0.009
Unemployment rate	-0.00903	0.005396	-1.67	0.105
Population growth lag	-5.0911	1.265668	-4.02	0
Energy consumption growth lag	0.001801	0.00088	2.05	0.05

The fitted BMA model in this study can be symbolized as follows:

$$GDP_i = 2.665 - 0.0017t - 0.0012Inflation_i + 0.168Export_i + 0.075Import_i - 0.029NO.Export_i + 0.0027EC_i + 0.025Log(Marginal_i) - 0.009Unemployment_i - 5.091Population_{i-1} + 0.0018EC_{i-1}$$

As the results of fitting this model show, all indicators of time (p-value=0.037), inflation rate (p-value=0.031), export growth (p-value=0.00), import growth (p-value=0.003), non-oil import growth (p-value=0.028), energy consumption growth (p-value=0.037), the logarithm of difference between official and unofficial rate of currency (p-value=0.009), population growth lag (p-value=0.00) are significantly effective on GDP growth in first type error level of 0.05. Yet, energy consumption growth lag (p-value=0.05) seems to have significant effects on the desired indicators. The unemployment rate (p-value=0.105) has not been also significantly effective on GDP growth at this level.

However, the noticeable issue in this model is its explanatory power in GDP changes. Table 6 shows the estimation of this model goodness of fit index, which is one of the best models found by the BMA method.

**Table 6: OLS Model Goodness of Fit Index, Documented from BMA Method**

Variable	Finding
F-statistics	23.05
Model significance level (P-value)	0.00
R2 determination coefficient	0.8848
Adjusted R2 determination coefficient (R <sup>2</sup> -Adjusted)	0.8464
Root Mean Square Error (RMSE)	0.02794

As the results of the Table show, the fitted model through the PLS method can justify up to 84.64% of existing changes in the values of GDP production by the variables, identified through the BMA method. The error criterion for this model has been also estimated very low equal to

0.027. Given the significance level of variance analysis test, done by F-statistics and its evaluation model properness, this model is significant and appropriate in first type error level of 0.05. To investigate the correlations between research variables and GDP growth schematically, their cross-correlation diagrams are proposed. Diagrams 1 to 7 represent these correlations in different lags.

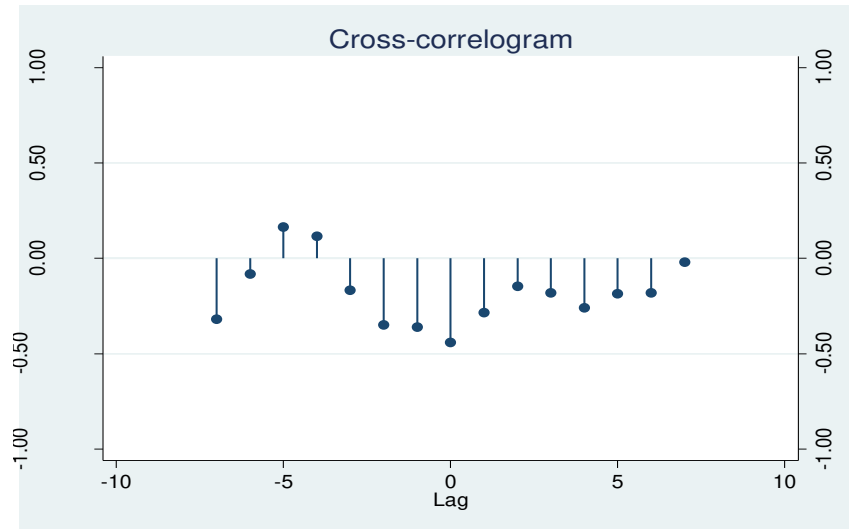


Diagram 1: Cross-correlation of GDP and Inflation Rate

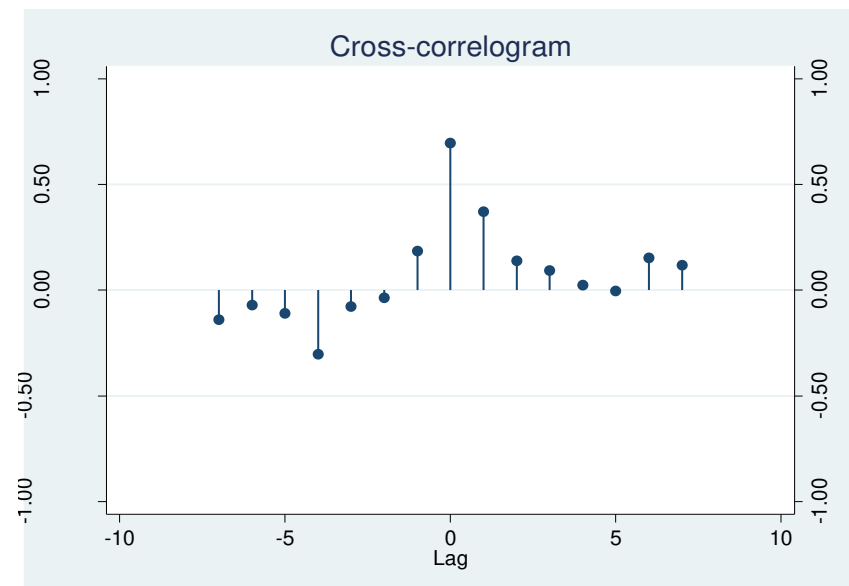


Diagram 2: Cross-correlation of GDP and Inflation Rate

As the above diagrams show, the inflation rate seems to correlate with GDP in zero lag while export growth has a very strong correlation with this variable in the zero lag, indicating the accuracy of the results of models fitting.



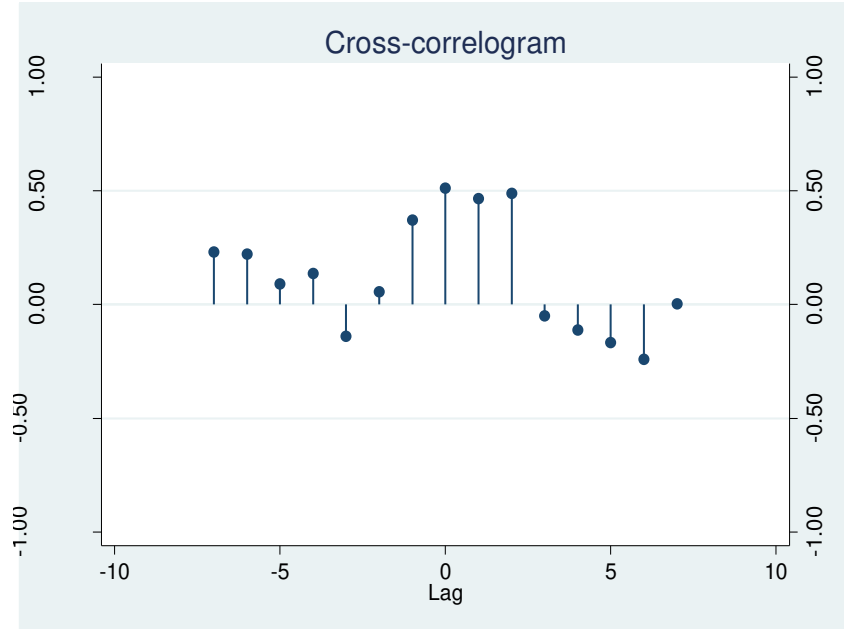


Diagram 3: Cross-correlation of GDP and Import Growth

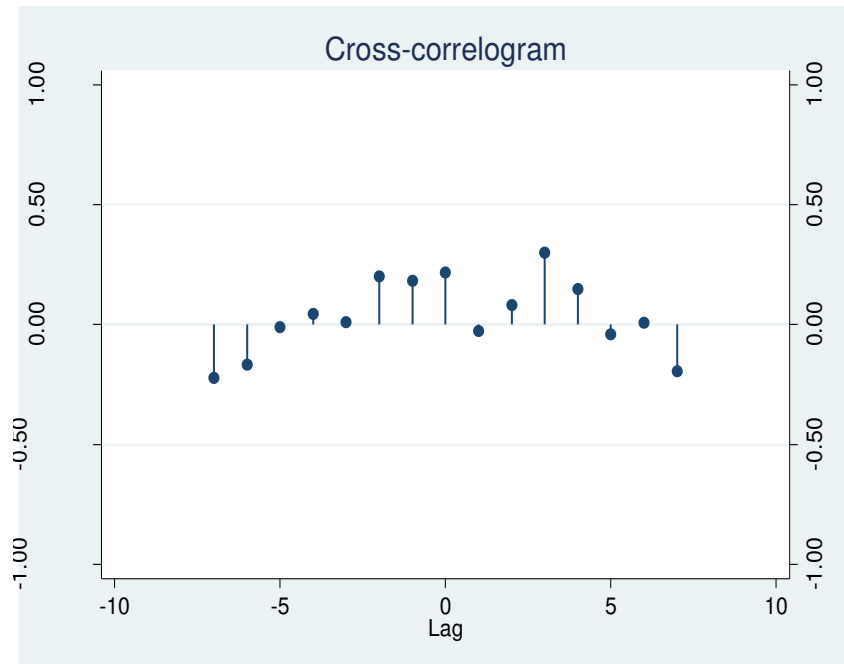


Diagram 4: Cross-correlation of GDP and Non-oil Export Growth

The above diagrams show that non-oil export growth seems not to correlate with GDP while import growth has an almost strong correlation with this variable in the zero, one, and two lag.

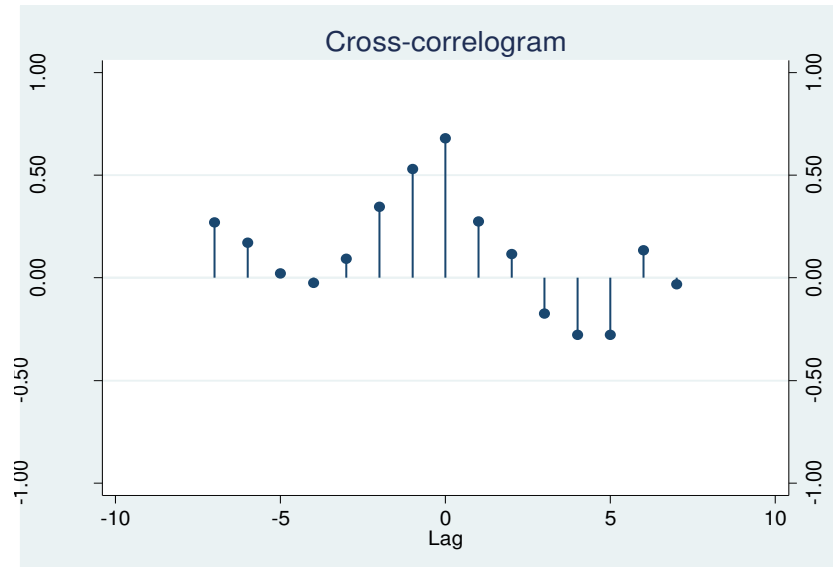


Diagram 5: Cross-correlation of GDP and Energy Consumption Growth

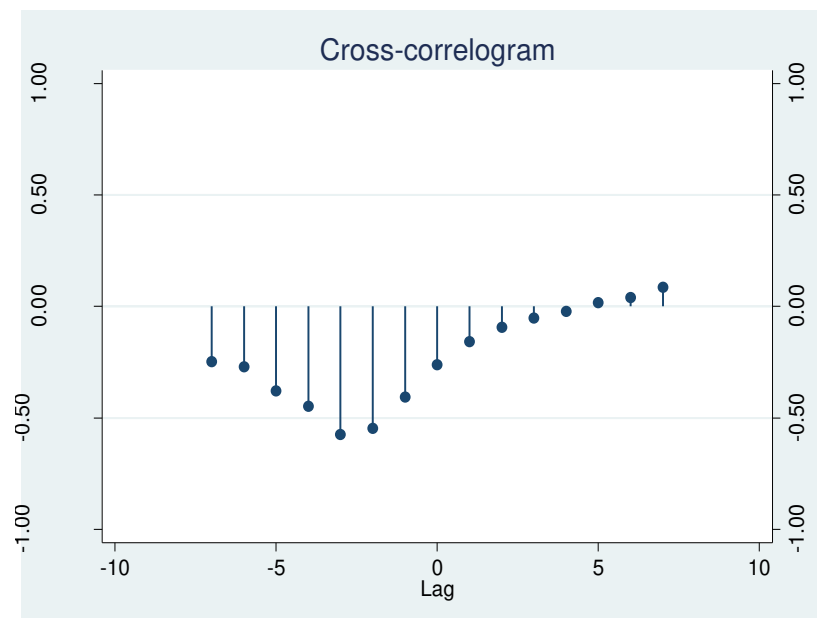


Diagram 6: Cross-correlation of GDP and the Logarithm of Difference between Official and Unofficial Rate of the Currency

As the above diagrams show, both indexes of energy consumption growth and the logarithm of the difference between the official and unofficial rates of currency seem to have a significant correlation with GDP in different lags.



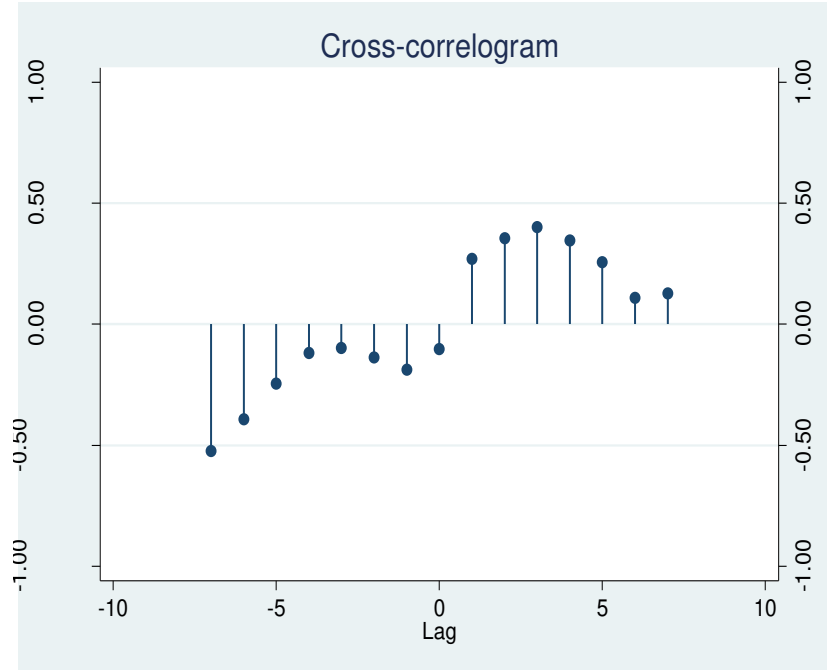


Diagram 7- Cross-correlation of GDP and Unemployment Rate

The above diagram shows that the unemployment rate is related to GDP in far lags. Given the existing sinusoidal process in this diagram, the relationship in the next lags is also likely.

#### DISCUSSION AND CONCLUSION

Although Iran is considered as one of the countries which provide the world energy and has rich energy savings, given the recent discussions about controlling energy consumption in Iran as well as targeted subscription, determining the relationship between energy consumption and production is of great importance.

The result of fitting all three models showed that economic growth in Iran, measured in this study using GDP growth, is affected by energy consumption growth, human and labor factors, population growth and other factors such as import and export growth, inflation and the difference between the official and unofficial exchange rates. As a result, the research hypotheses, based on the effect of energy consumption and physical and human asset on economic growth, was confirmed. Yet, energy consumption, as the most effective factor in economic growth, cannot be taken into account because the factors such as import and export growth have shown the highest effectiveness on GDP among all variables in all models of the study.

The Bayesian averaging method has had appropriate results, facing the models with numerous explanatory variables. In this method, model parameters and their significance, showing their effectiveness on the dependent variable, are estimated by the maximum posterior density of parameters. Therefore, if the posterior probability of the presence of a variable in the model is more than expected, the mentioned variable is admitted to be present in most of the possible models for fitting so is one of the necessary variables for the model. As a result, its effectiveness on the dependent variable is acceptable. This method fits the number of  $2^k$  possible models for

k-number explanatory variables and estimates the Bayesian estimation of parameters based on their posterior density mean in each model. The weighted mean of these estimations based on model posterior density has resulted in the final estimation of the parameter. According to the research process, the factors which have been significantly effective on GDP, are respectively assumed as export growth, energy consumption growth, import growth, and therefore the process of extracting variables with lag also finishes in this level which includes GDP lag, import growth lag, and unemployment lag.

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