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The Nexus between Energy Consumption Shocks and Economic Growth: Using BVAR Approach

Ezatollah Abbasian*, Salaheddin Manochehri

Abstract: This paper examines the nexus between economic growth and energy consumption shock, over the period 1990-2020, in Iran. We employ a Bayesian vector autoregressive (BVAR) with new prior functions, which will give results more acceptable consequences than the classical methods to study these relationships. This study estimates the relationship between energy consumption shocks and economic growth within a multivariate BVAR framework by including gross capital formation, Labor and carbon dioxide emission. The multivariate impulse responses to shocks in all the variables are obtained. The results show that, there is a positive impact of energy consumption shocks on economic growth in Iran and this means that energy consumption is crucial for economic growth. Also, the responses of economic growth to one-unit shock of gross capital formation and labor force are positive and the responses of economic growth to the one-unit shock of carbon dioxide emission is are negative.

Keywords: Bayesian VAR; economic growth; energy consumption; Iran

1 INTRODUCTION

Theoretically, there is a relationship between energy consumption and economic growth. This relationship can affect the people health status and the environment in the countries with high-energy consumption. In these countries, industry is responsible for 22% of global greenhouse gas emissions, results from burning fossil fuels for energy. Economists have considered the effect of energy consumption on economic growth in recent years. Since energy, consumption affects various aspects of economic activities, so it has an impact on a country’s efforts to achieve long-term economic growth. The two energy crises (1974 & 1981) have raised much empirical analysis as to relationship between energy consumption and economic growth [17, 10, 24, 32, 14, 19, 13, 18].

Ayres and Nair (1984) study, by biophysical growth model show that energy is the incite of growth via labor and capital energy consumption. Ref. [33] suggested the relationship between energy and output that influenced by substitution between energy and other production inputs, variation in technology, energy factor combination, products combination and also variation in other inputs combination. Ref. [28] investigates the dynamic relationship between energy consumption and economic growth in nine South and Southeast Asian countries using a panel data framework. The IRFs show that the shocks of energy consumption on economic growth, it takes a long time to achieve long-term balance. Ref. [12] show that both the non-renewable and the renewable energy consumption are positively increase economic growth for selected country of OECD. Ref. [25] analyze the effects of Energy security, electricity, population on economic growth in the case study of developing South Asian resource-rich economy. Basis on the results, a 1% increase in population increases electricity consumption by 4.16%. Ref. [6] and [31] assessed the nexus between renewable energy consumption and Economic growth in 26 European countries and China. Based on [6], a 1% increase in renewable energy consumption will increase economic growth by 0.054% in these countries. Ref. [31] showed that renewable energy, non-renewable energy, capital and labor have positive effect on economic growth.

Energy is one of the essential production factors that plays an important role in the economic, sociocultural, and political progress of countries. The development and implementation of energy policies, which can balance the energy supply and demand, are becoming a strategic issue, especially for energy-dependent countries [37]. The developing countries struggle to obtain energy sources reliable in the end to complete their economic development process, and the developed countries struggle to get them to keep their present prosperity levels [38].

This study analysis the effects of energy consumption shocks on economic growth using BVAR model in Iran. According to our finding, there is not any similar research paper in this topic. In this study, we specify the investigation in Iran, a country with high-energy resources and highly energy intensive. The main purpose of this study is to reveal any nexus between energy consumption shocks and economic growth in Iran using Bayesian Vector Autoregressive model. The paper is organized as follows: Section 2 reviews material and methodology; Section 3 and 4 presents the results and discussion, respectively, and section 5 presents the conclusion.

2 MATERIALS AND METHODOLOGY

Vector Autoregressive (VAR) models have a fundamental problem. This problem, called parameter abundance, in cases where observations are low (Iran), model forecasts inappropriate. Therefore, should look for a way to reduce the number of model parameters and constrain the models. Bayesian methods as a way of overcoming this problem have become increasingly used with researchers [16].

Bayesian models have three components. Prior density function, the posterior density function, and likelihood function. Therefore, it is important to select the appropriate prior function for the Bayesian models. Various prior functions have been used in Bayesian autoregressive models, the famous of which is Minnesota prior function that first introduced by [9]. The Bayesian methods are sensitive to the type of prior function used, in this paper four different prior functions are used to estimate the model and finally, using the RMSE index, selected the best prior function for calculate impulse response functions.

2.1 Bayesian Vector Autoregressive Model

The Bayesian approach is a recommended method for energy consumption and Energy resource melioration and CO_2 emissions in different fields [5]. Ref. [21] originally proposed a Bayesian approach to VAR estimation. The Bayesian model can be introduced by:

$$y_t = \beta x_t + \varepsilon_t \tag{1}$$

where $X_t = (I_n \otimes W_{t-1})$ is $n \times nk$ matrix, $W_{t-1} = (y'_{t-1}, y'_{t-2}, ..., y'_{t-p}, z'_t)$ is $k \times 1$, and $\beta = vec(b_1, b_2, ..., b_p, D)$ is $nk \times 1$ rank. The passive parameters are B and Σ.

Estimation of the parameters is entirely direct. By mixing the likelihood function of the parameters below:

$$L(y \mid \beta, \boldsymbol{\Sigma}) \alpha \mid \boldsymbol{\Sigma} \mid^{-\frac{T}{2}} \exp\left\{ -\frac{1}{2} \boldsymbol{\Sigma}_t (y_t - x_t \beta)' \boldsymbol{\Sigma}^{-1} (y_t - x_t \beta) \right\} \tag{2}$$

and the parameters, $p(B, \Sigma)$, obtained as follows [7].

$$p(\beta, \Sigma \mid y) = \frac{p(\beta, \Sigma) L(y \mid \beta, \Sigma)}{p(y)} \tag{3}$$

2.2 Priors

In this study, four priors' basis is used [11, 8, 30]:

1) The Litterman/Minnesota prior
2) The Normal-Wishart prior
3) The Sims-Zha normal-Wishart prior.
4) The Sims-Zha normal-flat.

2.3 Empirical Model and Data

Five variables including carbon dioxide emissions (*kt*) (CO_2), gross domestic product (US$) (GDP), capital formation constant (US$) (*K*), labor force (*L*) and energy consumption (millions tons) (EC) have been considered for the case study of Iran in this study. The data is collected over the period 1990-2020 from World Bank statistical resources and log form are consistency (*LCO2*, *LEC*, *LK*, *LL* and *LGDP*).

The regression based on the following function:

$$LGDP_t = f(LL_t, LK_t, LEC_t, LCO2_t) \tag{4}$$

The Bayesian VAR model used in this study, based on the study by [29], [12] and [28] and is given as:

$$\begin{aligned} &GDP_t K_t L_t EC_t CO2_t = z'_t c + \\ &+\sum_{j=1}^{2} (GDP_{t-j} K_{t-j} L_{t-j} EC_{t-j} CO2_{t-j}) A_j + \\ &+ (\varepsilon_t^{GDP} \varepsilon_t^{K} \varepsilon_t^{L} \varepsilon_t^{EC} \varepsilon_t^{CO2}) \end{aligned} \tag{5}$$

For $j = 1,…, N$ and $t = 1,…, T$.

Based on the Fig. 1, energy consumption in Iran has had a relatively increase trend, increasing by 176% over the period from 1990 to 2018. Between 1995 and 1996 and 1999 to 2000, energy consumption declined slightly and then increased.

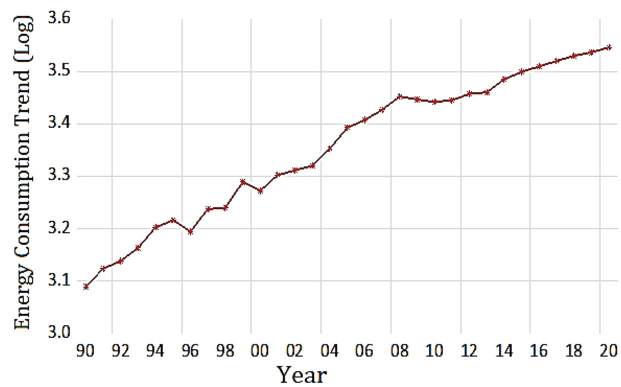

Figure 1 Energy consumption trend (Logarithmic)

According to Fig. 2, GDP growth in Iran has been relatively fluctuating, increasing and declining over time. The highest increase was for the period 2001 to 2008, which increased by 43% and the largest decrease was for the period 2011 to 2013, which decreased by 7.6%. During the total period, GDP in Iran increased by 135 percent.

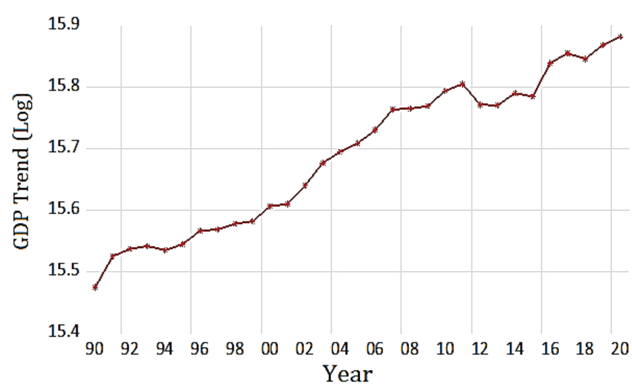

Figure 2 Gross domestic product (GDP) trend (Logarithmic)

3 RESULTS

Stationary test is ADF unit root test. Based on the Tab. 1, all variables are non-stationary at level but become stationary after first difference. Basis on Tab. 2 and results of tests, two period lagged values of the variables used in the analysis.

Table 1 Result of ADF unit-root test

Variables	Level	1st Difference
LCO_2	–1.35	–5.38*
LEC	–1.68	–6.96*
LGDP	–1.06	–5.27*
LK	–0.82	–3.97*
LL	–1.40	–2.66**

Note: * and ** denote significance at 1% and 5% level respectively

Table 2 Determination of optimum lag length for VAR model

Lag	*LR*	*AIC*	*SBC*	*FPE*	*HQ*
0	-	–19.40	–19.16	2.56e–15	–19.33
1	167.20*	–25.84	–24.39	4.28e–18	–25.42
2	35.30	–26.27*	–25.61*	3.54e–18*	–25.51*
3	25.56	–26.11	–23.03	3.93e–18	–24.46

Tab. 3 shows the results that is derived from the co-integration tests. Both tests reject the null hypothesis of zero co-integrating vectors. In the other hand; based on the co-integration test, the hypothesis that there is one co-integrating vector cannot be rejected, so there is no support for both variables in the system being stationary. Based solely on the evidence in Tab. 3, we would conclude that there exists a co-integrating relationship.

Table 3 Results from Co-Integration Test

Null hypothesis	J_{trace}	*p*-value	J_{max}	*p*-value
$r = 0$	84.73	0.002	30.57	0.017
$r = 1$	54.16	0.011	26.16	0.045
$r = 2$	27.99	0.079	16.44	0.200
$r = 3$	11.55	0.179	8.64	0.316

For comparing, the performance of different models and their goodness of fit in Bayesian econometric literature it is needed to evaluate their prediction accuracy. The predictions of each models that is mentioned above are presented in Tab. 4.

Table 4 Prediction one period ahead of variables

Prior function	$LCO2_{t+1}$	LEC_{t+1}	$LGDP_{t+1}$	LK_{t+1}	LL_{t+1}
Minnesota	5.61	3.32	15.66	15.17	7.30
Normal-Wishart	5.70	3.43	15.71	15.22	7.35
Sims-Zha (Normal-Wishart)	5.68	3.28	15.69	15.18	7.39
Sims-Zha (Normal-flat)	4.59	3.37	15.65	15.13	7.36
Real quantity	5.62	3.34	15.67	15.16	7.31

Some indexes such as *RMSE* are used to check the accuracy of prediction of different prior function. This index can be defined as follows:

$$RMSE = \sqrt{\frac{\sum_{\tau=\tau_0}^{T-h} \left[y_{i,\tau+h}^{0} - E(y_{i,\tau+h} \mid Data_\tau) \right]^2}{T - h - \tau_0 + 1}} \tag{6}$$

With considering τ_0 = 1990 and different forecast horizons from $h = 1$ to $h = 2$, we compared the predictions of each of the above prior function. Tab. 5 shows the RMSE index for different models and forecast horizons. The results show that the BVAR model using Minnesota prior function provides more accurate predictions than other priors do. Therefore, analyze the effect of energy consumption shocks on economic growth in Iran, using BVAR method with Minnesota prior function.

Table 5 RMSE Index Prediction

Prior function	One period ahead					Two period ahead				
	LCO2	*LEC*	*LGDP*	*LK*	*LL*	*LCO2*	*LEC*	*LGDP*	*LK*	*LL*
Minnesota	0.02	0.01	0.02	0.07	0.02	0.01	0.01	0.02	0.06	0.01
Normal-Wishart	0.03	0.03	0.03	0.08	0.02	0.02	0.02	0.02	0.06	0.02
Sims-Zha (Normal-Wishart)	0.02	0.03	0.02	0.11	0.02	0.02	0.01	0.04	0.09	0.02
Sims-Zha (Normal-flat)	0.02	0.03	0.02	0.09	0.05	0.01	0.02	0.04	0.07	0.03

3.1 Impulse Response Function

In this paper, such as [10] the reduced form VAR model and to identify the shocks the current Cholesky decomposition is used. In the VAR models to investigation the effect of a shock in a specific variable on other variables the impulse response functions are used. In addition, impulse response functions obtained with Minnesota prior function is analyzed. Fig. 3 (left hand and above) shows that, the carbon dioxide emission shock (*LCO2*) initially has a negative effect on economic growth that result according to those of [26, 2], which have the most negative impact in the third period and decrease after the third period in a stationary way. In addition, until second period, the effect of the energy consumption shock (*LEC*) (right hand and above) has been increasing and after the second period the effect of this shock has reduce and converged to its mean value, that result consenting to those of [6, 31, 15]. Gross fixed capital shock (*LK*) (left hand and low) has a positive effect on economic growth until the second period that result consenting to those of [31], and after the second period the effect of the shock has been reduced and fixed at its average value after 5 periods. The workforce (*LL*) (right hand and low) has an extra impact on economic growth from the beginning to the fifth period, this result according to those of [31], reaching its peak in 5 periods and then converging to its stable value.

3.2 Variance Decomposition

After entering a specific shock to the system, all variables are trend different from the predictions follow-up system. If we call the gap a prediction error, the analysis of the variance is called the percentage of the variance causes to the shock. In this study, we consider the forecasting error variance decomposition of the variable of economic growth. According to the estimated model based on Minnesota prior function, the results of the analysis of variance decomposition for ten periods are given in the Tab. 6.

Based on the Tab. 6, *S.E* columns shows the prediction error of economic growth that illustrated by depended and independed variables. During the total period, the prediction error is explained by the economic growth variable. The prediction error of the other variables in the model is increased during the period, so that in the second period the labor force (*LL*) shock explains 4.68% of the prediction error of economic growth, which is the highest, and in the other hand, the least explain (0.35%) is related to gross capital formation (*LK*). As the results in Tab. 6 show, in the following periods, the explanatory of prediction error of economic growth is increased by energy consumption, gross capital formation, CO_2 emission and labor force, which in the tenth period, 40.14% prediction error explain by economic growth and energy consumption, gross capital formation, CO_2 emission and labor force explain the prediction error of economic growth variable 1.02%, 0.19%, 18.72% and 39.90%, respectively, which the greatest and least effect is belong to labor force and gross capital formation shocks, respectively.

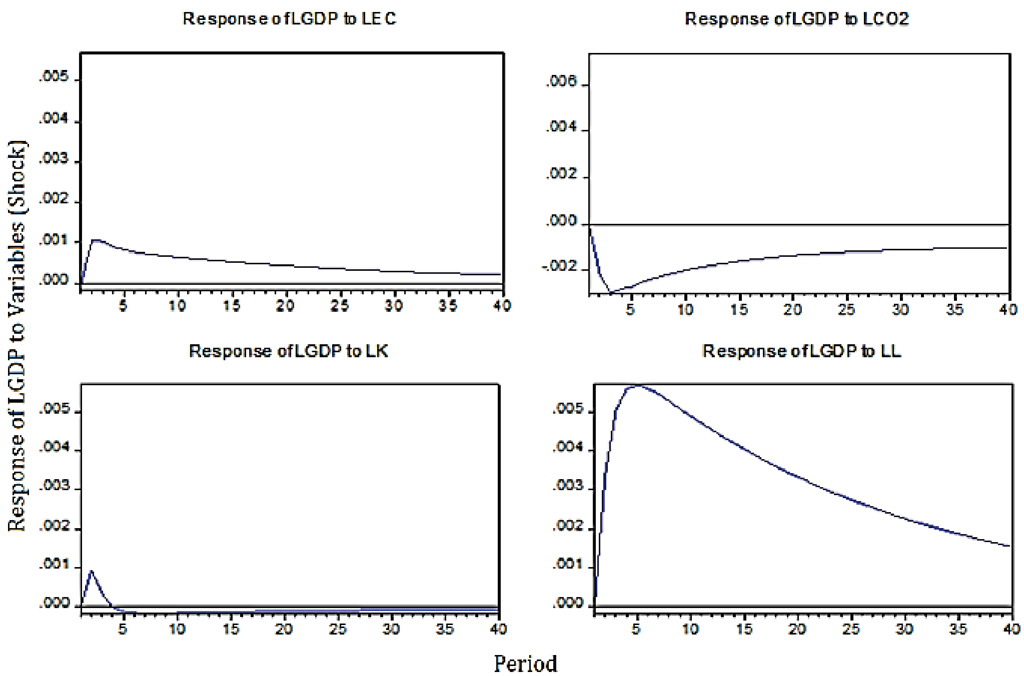

Figure 3 Impulse Response Function of Minnesota prior function

Table 6 Variance decomposition of Minnesota prior function

Period	*S.E*	*LGDP*	*LCO2*	*LEC*	*LK*	*LL*
1	0.014	100.00	0.00	0.00	0.00	0.00
2	0.015	91.35	3.14	0.44	0.35	4.68
3	0.016	78.50	7.58	0.75	0.341	12.80
4	0.018	67.63	10.93	0.88	0.29	20.25
5	0.019	59.43	13.33	0.95	0.26	26.01
6	0.020	53.35	15.06	0.98	0.23	30.35
7	0.021	48.77	16.34	1.00	0.22	33.65
8	0.022	45.22	17.32	1.01	0.20	36.22
9	0.023	42.41	18.10	1.02	0.19	38.25
10	0.024	40.14	18.72	1.02	0.19	39.90

Note: *S.E*: Prediction error variance of economic growth can be explained by exogenous shocks to the other variables; *LGDP*: Logarithm of Gross Domestic Product; *LCO2*: Logarithm of CO_2 emission; *LEC*: Logarithm of Energy Consumption; *LK*: Logarithm of Capital; *LL*: Logarithm of Labor.

4 DISCUSSION

The relationship between energy consumption and economic growth, especially after the first oil crisis in 1973 that increased oil prices, is one of the most important topics to study in the global economy context. The results of various studies in this field are not the same. The issue of energy in relation to the Iranian economy is important. Because Iranian economy is following the steps of realizing the price of energy carriers, and the question, which constantly raised is how the economic growth process will be affected by increasing the price of energy carriers and possible reduction of their consumption. Answering this question requires knowledge of the relationship between energy consumption and economic growth in the country and its dimensions. The main purpose of this study is to investigate the relationship between energy consumption and economic growth in Iran using BVAR model based on the objectives of the 20-year vision document of Iran. Capital and labor, are among the most important factors affecting economic growth that are considered in growth functions. In the new growth theories, the energy factor has also entered the model. Ref. [33] basis on ecological economists express that in biological models of growth, energy is the only and most important factor for growth, and since every production process needs energy, energy is always a factor in the production process. It is clear that the existence of energy source is a very important factor in the economic growth in Iran, because the effect of the energy consumption shock increase economic growth. Therefore, the result of this research confirms the importance of energy in economic growth in Iran, that result consenting to those of [6, 31, 15]. The results in this research have important implications for energy policy making in the Iran: given the high subsidies for energy, there is relatively more scope for more intensive energy conservation measures without severe impacts on economic growth. Indeed, it seems unlikely that the elimination of energy price distortions restrains the economic growth. However, subsidy reform should be embedded in a reform program that create broad support and yield wide-spreading benefits.

5 CONCLUSION

The energy economics literature lacks a consensus on what are the short and long run linkages along with the Granger causality direction between economic growth and energy consumption. This paper assesses The Impact of Energy Consumption Shocks on Economic Growth: Using BVAR Approach for 1990-2020 in Iran. In so doing, we control the relevant variables such as CO_2 emissions, labor force, and capital, and use BVAR modeling approach. Empirically, we tested the validity of our growth model in the time series dataset of Iran during the period of 1990 to 2020. For this purpose, we run the time series unit root tests as well as the Bayesian vector autoregressive (BVAR) estimations. This study can be the first paper that analyses the effects of the energy consumption shocks on economic growth in Iran using BVAR approach. This study evaluates the relationship between energy consumption shocks and economic growth within a multivariate BVAR framework by including gross capital formation, Labor and carbon dioxide emission (CO_2). The multivariate IF's are indicate by unit shocks to all the variables. (i.e. *LGDP*, *LEC*, *LK*, *LCO2* and *LL*). We found the positive impact of energy consumption shocks on the economic growth in Iran and this means that energy sources are crucial for the economic growth. The responses of economic growth to a one-unit shock of gross capital formation (*LK*) and labor force (*LL*) are positive and carbon dioxide emission (*LCO2*) shock on economic growth is negative.

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Authors' contacts:

Ezatollah Abbasian, Associate Professor in Economics
(Corresponding author)
Department of Public Administration,
Faculty of Management,
University of Tehran,
Tehran, Iran
E-mail: e.abbasian@ut.ac.ir

Salaheddin Manochehri, PhD Candidate in Economics
Faculty of Economics and Social Sciences,
Department of Economics,
Bu-Ali Sina University,
Hamedan, Iran
E-mail: s.manochehri@eco.basu.ac.ir