

Energy Consumption and Economic Growth: Kalman Filter Approach

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Abstract

This paper studies the relationship between energy consumption and economic growth for Iran during 1967-2008. We use time varying parameter (TVP) Approach to estimate effect of energy consumption on GDP over time. Our main finding is that energy consumption has a positive sign and it is statistically significant. The final coefficient is 0.037. This parameter varies trivially over time and fluctuations are rather stable.

Keywords: Consumption, Economic Growth, Filter Approach

Introduction

Impact of energy consumption on economic growth is as one of the most popular issues after the first oil shock in the field of energy economic. Studying this topic determines the relationship between energy consumption on economic development and provides the basis for discussion of energy policy and environmental conservation. Although economic theories don't explicitly specify this relationship, but there are many empirical studies in this area. Yu and Choi (1985), Ferguson et al. (2000), Toman and Jemelkova (2003) and Chontanawat et al. (2008) explain the lack of any clear results on the relationship between energy use and economic growth could be due to varying energy consumption patterns, the heterogeneity in climate conditions, the structure and stage of economic development within a country, different econometric methodologies employed and the presence of omitted variable bias along with varying time horizons of the studies conducted.

Kraft and Kraft (1978) is pioneering research for the years 1947 to 1974 were examined energy consumption and economic growth in America. The results show unidirectional causality from GDP to energy consumption dominates the economy of America. Akarca and Long (1980), Yu and Hwang (1984) found that energy consumption and GDP were independent in the United State. Lee and Chang (2005) examined the effect of energy consumption on economic growth in Taiwan from 1955 to 2003. Results of this study showed that economic growth and energy consumption have nonlinear dependence between variables. Studying Narayan and Smith (2007) also showed that investment, real GDP and energy consumption in G7 countries, are

integrated. Capital and energy in the long term caused to economic growth. Stern (1993, 2000), Lee (2006), Morimoto and Hope (2004), Glasure and Lee (1997), Yang (2000), Oh and Lee (2004), Paul and Bhattacharya (2004) found bidirectional causality between GDP and energy consumption. Cheng (1997), Masih and Masih (1997), Yemane (2004) and Lee (2005) found causality runs from energy consumption to GDP. Cheng and Lai (1997) found that a unidirectional causality runs from economic growth to energy consumption, thus suggested that an energy conservation policy is feasible. Nicholas Apergis & James E. Payne (2008) also investigated relationship between energy consumption and economic growth for six Central American countries over the period 1980-2004. This study showed the presence of long run causality from real GDP and economic growth.

The rest of paper is structured as follows. Section 2 provides methodology, TVP approach and state space model. Section 3 discusses the data, and empirical result. Concluding remarks are given in section 4.

Methodology

TVP approach and State-Space model

In this section we use time varying parameter approach (TVP) for estimating the effect of energy consumption on economic growth over period 1967-2009 in Iran.

This approach is a new method in econometric literature that provides estimating unobserved variable in the equation system. It can show different external shock such as change of regime, economic reform, political uncertainty and etc. So in this approach the parameter can vary over time. In addition, this doesn't need unit root test so it is one advantage of this method compared with other methods of time-series like OLS. State space model can estimate by Kalman-filter. It can evaluate maximum loglikelihood, forecasting and Smoothing state variable. Eq. (1, 2) is the general form of state - space the model.

$$Y_t = A'X_t + H'\xi_t + \omega_t \quad (1)$$

$$\xi_{t+1} = F\xi_t + v_{t+1} \quad (2)$$

Equation (1) is observation Equation and has the structure of linear regression model that the coefficient vector ξ varies over time and equation (2) is a state equation. It represents a first order vector autoregressive model, the Markovian nature of which accounts for many of the elegant properties of state space model. (Durbin and Koopman, 2001)

Where Y_t is a $p \times 1$ vector of observations and X_t is a $p \times k$ matrix of explanatory variables. ξ_t is a

vector of unobservable variables called state vector. ω_t and v_{t+1} are noises. So that:

$$\text{var}(\omega_t) = K_t, \text{var}(v_t) = Q_t, E(\omega_s v_t) = 0 \quad (3)$$

X_t in eq. (1) contains exogenous variables that don't explain any information about ω_{t+s}, ξ_{t+s}

for $s = 0, 1, \dots, N$. On the other hand X_t can include lag of depended variables which don't

correlation with ω_{t+s} and ξ_{t+s} . Moreover, we assume:

$$E(v_t \xi_t') = 0, E(\omega_t \xi_t') = 0 \quad (4)$$

Based on the above, two major application filter – Kalman are:

- 1- The first application of this filtering is providing an algorithm for forecasting the least squares state vector based on T observations. So:

$$\xi_{t+1|t} = E(\xi_{t+1} | Y_t), Y_t = (y_t', y_{t-1}', \dots, y_1', x_t', x_{t-1}', \dots, x_1') \quad (5)$$

2- The second application is estimating varying parameter over time. Consider the following equation:

$$Y_t = X_t' \beta + \omega_t \quad (6)$$

Where X_t is an exogenous vector and independent of ω_t , so Coefficients vector of parameters that varies overtime as follow:

$$\beta_{jt} = \varphi_j \beta_{jt-1} + e_{jt} \quad (7)$$

If we set $\varphi_j=1$, eq. (5) can follow as random walk that represented as follow:

$$\beta_{jt} = \beta_{jt-1} + e_{jt} \quad (8)$$

The above equation e_{jt} shows the external shocks that entry to system. So it can be result of transition economic regime or changes in economic policy at time t (Song and Witt).

Eq(6) can be written in the form:

$$\beta_{jt} = \beta_{j0} + \sum_{h=0}^n e_{jt-k} \quad (9)$$

Structure of state equation is specified by information criteria. For example (Grinlid and Hall, 1996) (kim1993) (song & witt 2000) showed Random walk process for state equation can consider structural changes on economic model. Note for deciding on the appropriate state equation, different information criteria such as Akaike or schwarz criterion and also ARMA should be used. (Harvey, 1987)

Empirical result

If we consider economic output (Y) as a function of labor (L), capital (K) and energy consumption (EC), spired from Lee and Chang (2008) and Stern (2000a, b), the relation is specifies as:

$$Y_t = f(K_t, L_t, EC_t) \quad (10)$$

Based on TVP approach and using Kalman- filter approach, the measurement and state equations are as:

$$GY_t = \beta_0 + \beta_1 GK_t + \beta_2 GL_t + \beta_3 GEC_t + \varepsilon_t \quad (11)$$

$$GEC_t = \varphi_j GEC_{jt-1} + e_{jt} \quad (12)$$

Where GY_t is a domestic production growth, GK_t is a stock capital growth, GL_t is population growth and GEC_t is energy consumption growth. Data are from central bank of Islamic republic Iran. Table 1 show the result of specification.

Table1:

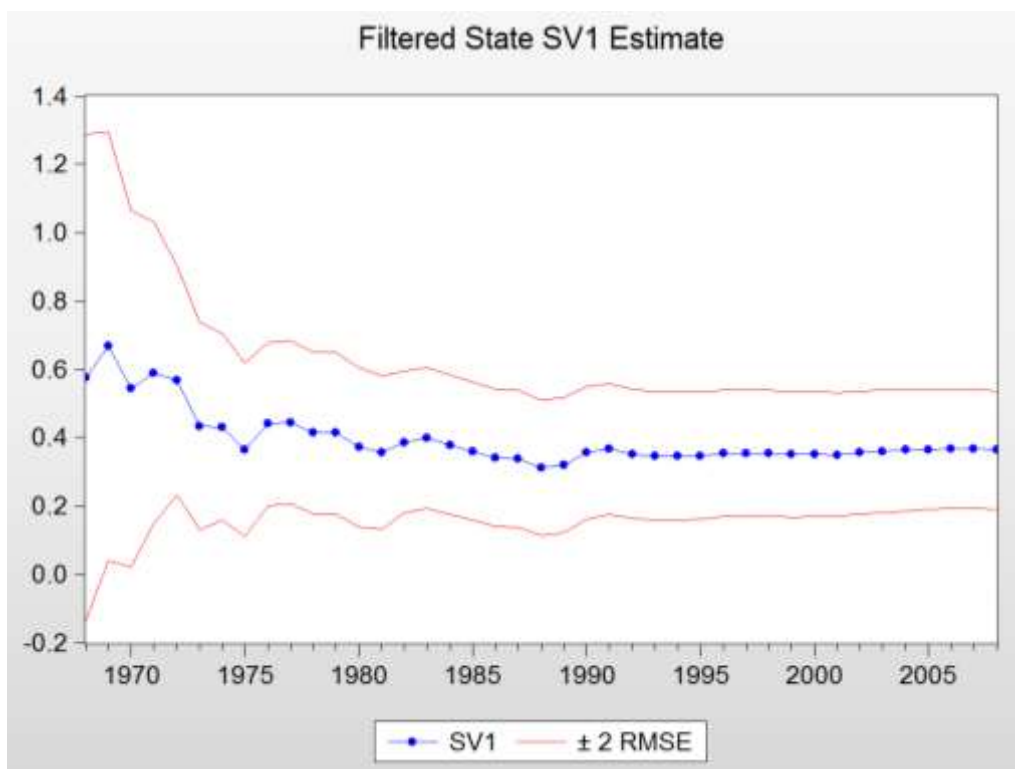
Model Estimated With Time Varying Parameter (Tvp)

explanatory				state variable
Constant term	Labor	Capital	gdp(-1)	Final State(ec)
-0.002347	-	0.079413*	0.40047***	0.370426***
(0.043563)	(0.10869)	-(1.73695)	(2.935926)	(4.260666)
Log likelihood	54.46528			
Akaike info criterion	- 2.355489			
Schwarz criterion	- 2.148624			
Hannan-Quinn criter.	- 2.279665			

The numbers in parameters are absolute values of the estimated z statistic. *, **, *** denote that the corresponding null hypothesis can be rejected at the 10, 5, 1, percent significant level, respectively.

Preliminary estimations implies that the coefficients for labor growth, capital growth, and lag GDP growth as rather constant. So, we assume just the coefficient of growth consumption can vary as a random walk.

Figure 1 show state variable(the coefficient of growth consumption)over time.It is clear this parameter is stable as well as other parameters over time except the primary years. Ten percent decrease in energy consumption growth lead to approximately 0.37 percent decrease in economic growth.



Conclusion and policy implications

This paper provides new empirical insight into the analysis of the relationship between energy consumption and economic growth, considering time varying approach. Result shows TVP approach is suitable for representation of structural changes. The findings indicate energy consumption has a positive sign in GDP equation. Moreover, the final coefficient estimated as 0.37 is statistically significant. This parameter varies trivially over time so that the fluctuations are rather stable. The size of coefficient (0.37) implies the energy conservation policies have a restrictive strong effect on economic growth.

Because of the importance of the relationship between economic growth and energy consumption, we suggest policy makers to be careful about energy conservation policy.

References

- Akarca, A.T., Long, T.V., 1980, on the relationship between energy and GNP: a re-examination, *J. Energy Development*, 5 (1980), pp. 326–331
- Al-Iriani, M.A., 2006, Energy–GDP relationship revisited: an example from GCC countries using panel causality, *Energy Policy*, 34 (17) (2006), pp. 3342–3350
- Apergis, N., Payne, J.E., 2009, Energy consumption and economic growth in Central America: Evidence from a panel cointegration and error correction model, *Energy Economics*, Volume 31, Issue 2, March 2009, Pages 211–216
- Asafu-Adjaye, J., 2000, the relationship between energy consumption, energy prices and economic growth: time series evidence from Asian developing countries. *Energy Economics*, 22 (2000), pp. 615–625
- Bhattacharya, R.N., Paul, S., 2001, Sectoral changes in consumption and intensity of energy in India, *Indian Economic Review*, xxxvi (2) (2001), pp. 381–392
- Central Bank Of Islamic Republic Of Iran, Economic Time Series Data Base

- Cheng, B.S., 1997, Energy consumption and economic growth in Brazil, Mexico and Venezuela: a time series analysis, *Applied Economics Letters*, 4 (1997), pp. 671–674
- Cheng, B.S., 1999, Causality between energy consumption and economic growth in India: an application of cointegration and error-correction modeling, *Indian Economic Review*, xxxiv (1) (1999), pp. 39–49
- Cheng, B.S., Lai, T.W., 1997, An investigation of co-integration and causality between energy consumption and economic activity in Taiwan, *Energy Economics*, 19 (1997), pp. 435–444
- Chontanawat, J., Hunt, L.C., Pierse, R., 2008, Does energy consumption cause economic growth? Evidence from a systematic study of over 100 countries, *Journal of Policy Modeling* 30(2008), pp. 209–220
- Durbin, J., Koopman, S.J., (2008), *Time series analysis by state space methods*, Oxford Statistical Science Series, Oxford University Press,
- Glasure, Y.U., 2002, Energy and national income in Korea: further evidence on the role of omitted variables *Energy Economics*, 24 (2002), pp. 355–365
- Glasure, Y.U., Lee, A.R., 1998, Cointegration, error-correction, and the relationship between GDP and electricity: the case of South Korea and Singapore, *Resource and Energy Economics*, 20 (1998), pp. 17–25
- Harvey, A.C. (1987). *Application of Kalman Filter in econometric in advanced econometrics: fitted world congress*. Cambridge university press, 1:285–313
- Kraft, J., Kraft A., 1978, on the relationship between energy and GNP, *Journal of Energy and Development*, 3 (1978), pp. 401–403
- Lee, C.C., 2005, Energy consumption and GDP in developing countries: a cointegrated panel analysis, *Energy Economics*, 27 (2005), pp. 415–427
- Lee, C.C., 2006, the causality relationship between energy consumption and GDP in G-11 countries revisited, *Energy Policy*, 34 (2006), pp. 1086–1093
- Lee, C.C., Chang, C.P., 2005, Structural breaks, energy consumption, and economic growth revisited: evidence from Taiwan, *Energy Economics*, 27 (2005), pp. 857–872
- Lee, C.C., Chang, C.P., 2008, New evidence on the convergence of per capita carbon dioxide emissions from panel seemingly unrelated regressions augmented Dickey–Fuller tests, *Energy* 33 (9), 1468–1475
- Masih, A.M.M., Masih, R., 1997, On the temporal relationship between energy consumption, real income and prices: some new evidence from Asian-energy dependent NICs based on a multivariate cointegration and error-correction approach, *Journal of Policy Modeling*, 19 (1997), pp. 417–440
- Masih, A.M.M., Masih, R., 1997, On the temporal relationship between energy consumption, real income and prices: some new evidence from Asian-energy dependent NICs based on a multivariate cointegration and error-correction approach, *Journal of Policy Modeling*, 19 (1997), pp. 417–440
- Morimoto, R., Hope, C., (2004), The impact of electricity supply on economic growth in Sri Lanka, *Energy Economics* 26 (1), 77–85
- Oh, W., Lee, K., 2004, Causal relationship between energy consumption and GDP revisited: the case of Korea 1970–1999, *Energy Economics*, 26 (2004), pp. 51–59
- Narayan, P., Smyth, R. (2007), Electricity consumption, Employment and real income in Australia: evidence from multivariate Granger causality tests, *Energy policy*, 33, pp. 1109–1116
- Song, H. Witt, S.F., 2000, *Tourism demand modeling and forecasting*, modern econometrics approach. Oxford, UK, Pergomen.

- Song, H.Witt, S.F., 2003, Tourism forecasting: The general to specific approach.journal of travel research, 42:65-74.
- Song H, Wong, K.F., 2003, Tourism demand modeling:a time varying parameter approach.journaloftravel research,42:52-74
- Stern, D.I., 1993, Energy and growth in the USA: a multivariate approach, Energy Economics, 15 (1993), pp. 137–150
- Stern, D,I.,2000,a multivariate cointegration analysis of the role of energy in the US macroeconomy. Energy economics15, 137-150
- Toman,M.A.,Jemelkova,B.(2003).Energy demand and economic development:An assessment of the state of knoeledge.The energy journal,24,93-112
- Yang, H.Y., 2000, Anote on the causal relationship between energy and GDP in Taiwan,Energy Economics, 22 (2000), pp. 309–317
- Yemane, W.-R., 2004, Disaggregated industrial energy consumption and GDP: the case of Shanghai,Energy Economics, 26 (2004), pp. 69–75
- Yu, E.S.H., Hwang,B.K.,The relationship between energy and GNP: further results,Energy Economics, 6 (1984), pp. 186–190
- Yu,E.S.H., Choi,J.Y., 1985, The causal relationship between energy and GNP: an international comparison,Journal of Energy and Development, 10 (1985), pp. 249–272
- Yu, E.S.H., Hwang, B.K., 1984, therelationship between energy and GNP: further results, Energy Economics, 6 (1984), pp. 168–190