Quarterly Journal of Quantitative Economics(JQE) **(2024) 21(3) 145-183**

Shahid Chamran University of Ahvaz

Quarterly Journal of Quantitative Economics

Journal Homepage: www.jqe.scu.ac.ir
Print ISSN: 2008-5850
Online ISSN: 2717-4271

Application of the Fuzzy Nonlinear Model to Investigate the Factors Affecting Energy Consumption and Efficiency in Iran

Mojtabi Bahmani *, Reza Ashraf Ganjoei **, Mansoura Murad Alizadeh ***

** Associate Professor of Economics, Department of Economics, Faculty of Management and Economics, Shahid Bahonar University of Kerman, Kerman, Iran (corresponding author).*
Email: *mbahmani@uk.ac.ir*

0000-0003-0257-5775
Postal address*: Kerman, Imam Khomeini Highway, Research Square of Shahid Bahonar University, Kerman, Postal code: 7616913439.*

*** Assistant Professor, Economics Department, Faculty of Economics and Management, University of Sistan and Baluchestan, Zahedan, Iran.*
.Email: reza_ash@eco.usb.ac.ir
**** Master's student in Economics, Department of Economics, Faculty of Management and Economics, Shahid Bahonar University of Kerman, Kerman, Iran*
Email: *mansoreh.maz@gmail.com*

ARTICLE HISTORY	JEL CLASSIFICATION	KEYWORDS
Received: 18 January 2022 ***Revision: 29 July 2022*** ***Acceptance: 03 December 2022***	***Q43 ،Q41 ،B41 ،R29***	***Fuzzy Nonlinear Regression, Energy Consumption, Energy Efficiency***

Acknowledgments: Acknowledgments may be made to individuals or institutions that have made an important contribution.
Conflict of Interest: The authors declare no conflict of interest.
Funding: The authors received no financial support for the research, authorship, and publication of this article.

Shahid Chamran University of Ahvaz
Quarterly Journal of Quantitative Economics
(former Economic Studies)

How to Cite:
Bahmani, Mojtabi., Ashraf Ganjavii, Reza. & Murad Alizadeh, Mansoura. (2024). Application of the Fuzzy Nonlinear Model to Investigate the Factors Affecting Energy Consumption and Efficiency in Iran. *Quarterly Journal of Quantitative Economics(JQE)*, 21(3), 145-183. [in persian]
10.22055/jqe.2022.39807.2460

EXTENDED ABSTRACT

INTRODUCTION

Today, in the economies of all countries, both developed and developing, increasing productivity and optimal energy consumption has become a national priority Productivity is a standard for evaluating the performance of systems and determining the degree of success or failure in achieving the goals of the system with regard to resource consumption. Considering the growth in energy consumption, the optimization of energy consumption in order to protect the environment, provide security of supply protection of national resources and wealth, and address intergenerational issues has become one of the important priorities of the country. Increasing productivity at the national level will increase people's living standards, reduce inflation, and create national competitiveness in global markets. Increasing national productivity is the result of increasing productivity in organizations, institutions, and economic enterprises. Therefore, considering to the importance of this issue in the national economy, this research the purpose of this research isaimed to investigate the factors affecting energy consumption and efficiency. For this purpose, the fuzzy regression model, which has great explanatory power in this field, was used to investigate this issue. Econometric models need complete and definite information to be accurate considering that energy consumption and efficiency are constantly fluctuating, being able to model this uncertainty is a necessity.

METHODOLOGY

In this article, to investigate the factors affecting energy consumption and efficiency in Iran, the autoregression model of soft fuzzy logistic transfer was used due to its flexibility in modeling for the time period of 1990-2019, and MATLAB software was used to estimate the membership functions.

FINDINGS

The results of the linear and nonlinear fuzzy models indicated that the energy consumption estimation of the fuzzy nonlinear model has significantly increased the explanatory power of the model the coefficient of determination in the fuzzy nonlinear model is 0.64, while it is 0.41 in the linear model. Because non-linear models model the behavior of economic variables more accurately than linear models, the coefficient of determination of the non-linear model is higher compared to the linear model. Based on the estimation results of the nonlinear model, the transmission speed for energy consumption is 2.5, which indicates a high adjustment speed in energy consumption. In addition, the threshold value for energy consumption is 8.1. Also, the linear model of energy consumption shows that technology and gas and oil prices reduce energy consumption. On the other hand, the added value of the industrial sector and economic growth increase energy consumption. The results of the fuzzy nonlinear model are completely different from the linear model, because the economic variables have a nonlinear behavior, so it is necessary to model these nonlinear behaviors using nonlinear models to make the proper analysis of the effect of different variables possible.

CONCLUSION

According to the study results, three numbers can be obtained for how the investigated variables affect the dynamics of energy consumption and efficiency. For this purpose, we examined the three cases of high threshold, low threshold, and middle threshold (when the emission of carbon dioxide gas and the price of gas are equal to the threshold value).

Regarding how the rate of carbon dioxide gas emission affects energy efficiency, as we approach the low threshold, the effect of carbon dioxide gas emission increases significantly however, this effect decreases at the high threshold. One of the reasons for this is the increase of energy consumption at a high threshold, which necessitates the optimal use of energy and higher use of technology in order to reduce environmental damage. The impact of fixed investments on energy efficiency is positive and it stabilizes as it approaches the low and middle thresholds, but this effect increases at the high

Shahid Chamran University of Ahvaz
Quarterly Journal of Quantitative Economics
(former Economic Studies)

threshold. Fixed investment can have a significant impact on increasing energy efficiency in the country. Sectors such as industry, household public and private buildings, transportation, construction, and agriculture are among the most important sectors in which energy efficiency can be increased by increasing large investments. Also, added value and technology have a greater impact on energy efficiency at the high threshold level and the impact decreases at the middle and low threshold levels. Added value and technology improve the partial and total efficacy of production factors, which plays a significant role in increasing productivity.

The price of gas and oil has caused an increase in energy efficiency, which has the greatest effect at the upper threshold, and this effect decreases as weapproach the lower threshold. This points to the effectiveness of increase in energy prices on the productivity index energy-capital substitution elasticity and labor supply. With a coordinated increase in the price of energy carriers, if it is not possible to substitute energy with other production factorsproduction will decrease, and the increase in prices will not have a significant effect on productivity and consumption indices. If the substitution between the factors is possible, production will not change with reduction in consumption and the productivity index will improve.

The results of the fuzzy nonlinear model of the estimation of the effect of independent variables on energy consumption at each of the three mentioned thresholds indicate that the variables have almost the same effect, which is related to the characteristics of energy consumption. Regarding the percentage change of carbon dioxide emission rate on energy consumption, there is no significant reduction at the low and middle threshold however, this effect decreases at the high threshold. The impact of fixed investments on energy consumption is positive and is almost stable at the low and middle thresholds, but this influence increases at the high threshold. Also, the impact of technology on energy consumption is almost the same at all three thresholds although it decreases at the high threshold. The price of gas and oil reduces energy consumption. Also, Netich shows that it has the greatest effect at the upper threshold and this effect increases as it approaches the lower threshold. Regarding the effect of economic growth on energy consumption, the results indicate a direct relationship between these two variables, with the greatest effect on energy consumption observed at the high threshold.

Reference

Abdoli, G., & Varahrami, V. (2010). A Survey Of The Effects Of Technological Advance On Energy Saving In The Industrial And Agricultural Sectors Of Iran Based On The Cobb - Douglas Production Function. *Quarterly Energy Economics Review 6*(23). Retrieved from https://www.sid.ir/paper/99557/en

Abrishami, H., Nouri, M., & Doudabinezhad, A. (2010). The Relationship Between Energy Productivity and Energy Price in Iran: An Asymmetric Cointegration Approach. *Quarterly Journal of Economic Research and Policies, 18* .۵-۲۲ ,(۵۵)Retrieved from http://qjerp.ir/article-1-228-en.html

Adenikinju, A. F., & Alaba, O. B. (1999). Energy use and productivity performance in the Nigerian manufacturing sector (1970-90). *Opec review*, *23*(3), 251-264 .

Ahmadi Shadmehri, M. T., Falahi, M. A., & Niazi Mohseni, M. (2014). Analyzing Factors Affecting on the Energy Productivity in Iranâ€ ™s Agricultural Sector. *Agricultural Economics and Development*, *21*(4), 1-28. Retrieved from http://aead.agri-peri.ac.ir/article_58716_219fa231b45e7db4241۹eb5d76ab14d3.pdf

Akbarnia, E. s., Salehi, S., Firozjayan, A. A., & Heidari, G. (2022). Identification of Effective Sociological Factors on Household Consumption Energy (A Systematic Review on Energy Studies in Iran). *Quarterly of Social Studies and Research in Iran, 11*(2), 305-345. doi:10.22059/jisr.2022.330234.1237

Amini, A., & Yazdipoor, F. (2008). An Analysis of Factors Effecting Energy Productivity in Large Manufacturing Firms: A Case Study of Iran. *Economics Research*, *8*(30), 71-104. Retrieved from https://joer.atu.ac.ir/article_3206_a9a54c9cee9da60e7be6e56573f292af.pdf

Ang, J. B. (2007). CO2 emissions, energy consumption, and output in France. *Energy Policy*, *35*(10), 4772-4778 .

Anooshehpour, A., Moghaddasi, R., MohammadiNejad, A., & Yazdani, S. (202 .(۰The Relationship between Energy Consumption and Total Factor Productivity in Agriculture: Application of Quantile Regression Approach. *Iranian Energy Economics*, *9*(34), 65-85. doi:10.22054/jiee.2021.56060.1789

Apergis, N., & Payne, J. E. (2010). Renewable energy consumption and economic growth: evidence from a panel of OECD countries. *Energy Policy, 38*(1), 656-660 .

Apergis, N., Payne, J. E., Menyah, K., & Wolde-Rufael, Y. (2010). On the causal dynamics between emissions, nuclear energy, renewable energy, and economic growth. *Ecological economics, 69*(11), 2255-2260 .

Arabshahi Delouee, M., Falahi, M. A., & Salehnia, N. (2020). Energy Efficiency of Energy-Intensive Industries in Iran: Application of Data Envelopment Analysis and Gamma Test. *Quarterly Journal of Energy Policy and Planning Research, 6*(3), 45-84. Retrieved from http://epprjournal.ir/article-1-827-en.html

Asadi, A., & Esmaeili, S. M. (2013). Investigate the Dynamic Relationship between Energy consumption and Financial development in Iran. *Quarterly Journal of The Macro and Strategic Policies, 1*(Vol1-No3), 17-38 .

Asadi, A., Esmaili, S. M., Bakhshour, F., & Sadeghpour, A. (2018). Investigating Factors Affecting Energy Consumption in Iran(with Emphasis on the Financial Development Variable) .*quarterly journal of fiscal and Economic policies, 6*(21), 81-107. Retrieved from http://qjfep.ir/article-1-852-en.html

Baniasadi, M., & Mohseni, R. (2014). The effect of temporary and permanent shocks of productivity on intensity of energy consumption in Iran (Application of Blanchard-Quah method) .

Behbudi, D., & Asgharpour, H. (2009). Structural Breaks, Energy Consumption and Economic Growth in Iran (1967-2005). *The Economic Research, 9*(3), 53-84. Retrieved from http://ecor.modares.ac.ir/article-18-6941-en.html

Belke, A., Dobnik, F., & Dreger, C. (2011). Energy consumption and economic growth: New insights into the cointegration relationship. *Energy Economics, 33*(5), 782-789 .

Cohen, F., Glachant, M., & Söderberg, M. (2015). *The impact of energy prices on energy efficiency: Evidence from the UK refrigerator market*. Retrieved from

Delnajian, S., Soheili, K., & Beharipour, S. (2015). Evaluation Of The Effect Of Changing Population Age Structures On Household Sector

Energy Consumption In Iran. *Quarterly Journal of Quantitative Economics, 12*(2), 105-135. doi:10.22055/jqe.2015.11886

Ebrahimi, M., & Alemorad-jabdarghi, M. (2012). Financial Markets Development and Energy Consumption in D8 Countries. *Quarterly Journal of Economic Research and Policies, 20* .۱۵۹-۱۷۴ ,(۶۱) Retrieved from http://qjerp.ir/article-1-178-en.html

Ehsanfar, M. H. (2016). Explaining The Effect of Economic Growth and Energy Market Integration on Energy Consumption in Iran: Using Generalized Method of Moments. *Economic Growth and Development Research, 7*(25), 85-96. Retrieved from https://egdr.journals.pnu.ac.ir/article_2589_09c7e427b7b72903c3a9f8592a602803.pdf

Feng, Y., Lu, C.-C., Lin, I.-F., Yang, A.-C., & Lin, P.-C. (2022). Total Factor Energy Efficiency of China's Thermal Power Industry . *Sustainability, 14*(1), 504 .

Ghaderi Moghadam, R., Baseri, B., Falihi, N., & Abbasi, G. (2022). The Role of Inflation Uncertainty onGas and Oil Consumption. *Financial Economics, 16*(59), 47-74. doi:10.30495/fed.2022.694713

Ghanbari, A., Khaksar Astana, S & ,.Khaksar Astana, H. (2014). Factors Affecting Energy Productivity in Agricultural Sector of Iran. *Agricultural Economics Research, 6*(21), 1-21. Retrieved from https://jae.marvdasht.iau.ir/article_415_ac05e1702039ac464deaf998486e6562.pdf

Ghosh, S. (201 .(۰Examining carbon emissions economic growth nexus for India: a multivariate cointegration approach. *Energy Policy, 38*(6), 3008-3014 .

Hatzigeorgiou, E., Polatidis, H., & Haralambopoulos, D. (2011). CO2 emissions, GDP and energy intensity: a multivariate cointegration and causality analysis for Greece, 1977–2007. *Applied Energy, 88*(4), 1377-1385 .

Hoshmand, M., Daneshnia, M., Sotudeh, A., & Ghezelbash, A. (2013). Causality relationship between energy consumption, economic growth and prices: using panel data OPEC member countries .

Jacques Loesse, E. (2010). The Energy Consumption-Growth Nexus in Seven Sub-Saharan African Countries". *Economics Bulletin, 30*(2), 1191-1209 .

Jalalabadi, A., & Rakhshan, S. (2005). An Analysis of Consumption Pattern of Energy Carriers in Iran (1966-2000). *Iranian Journal of Economic Research, 7*(22), 115-132. Retrieved from https://ijer.atu.ac.ir/article_3778_658bbd005edd9c65d65dda1097bdea72.pdf

Kafaie, S. M. A., & Nejadaghaeianvash, P. (2017). Identifying the Factors that Effect Sectoral Energy Efficiency in the Iranian Economy. *Quarterely Energy Economics Review, 13*(52), 1-34. Retrieved from http://iiesj.ir/article-1-706-en.html

Kakar, Z. K., Khilji, B. A., & Khan, M. J. (2011). Financial development and energy consumption :empirical evidence from Pakistan. *International Journal of Trade, Economics and Finance, 2*(6), 469 .

Karanfil, F. (2009). How many times again will we examine the energy-income nexus using a limited range of traditional econometric tools? Energy Policy, 37(4), 1191-1194.

Kronenberg, T. (2009). The impact of demographic change on energy use and greenhouse gas emissions in Germany. *Ecological economics, 68*(10), 2637-2645 .

Lee, C.-C., & Lee, J.-D. (2010). A panel data analysis of the demand for total energy and electricity in OECD countries. *The Energy Journal, 31* .(۱)

Liddle, B., & Lung, S. (2010). Age-structure, urbanization, and climate change in developed countries: revisiting STIRPAT for disaggregated population and consumption-related environmental impacts. *Population and Environment, 31*(5), 317-343 .

Lin, B., & Moubarak, M. (2014). Renewable energy consumption–economic growth nexus for China. *Renewable and Sustainable Energy Reviews, 40*, 111-117 .

Lopes, H. F., & Salazar, E. (2006). Time series mean level and stochastic volatility modeling by smooth transition autoregressions: a Bayesian approach. In *Econometric Analysis of Financial and Economic Time Series*: Emerald Group Publishing Limited.

López-Bernabé, E., Foudi, S., Linares, P., & Galarraga ,I. (2021). Factors affecting energy-efficiency investment in the hotel industry: Survey results from Spain. *Energy Efficiency, 14*(4), 1-22 .

Luukkonen, R., Saikkonen, P., & Teräsvirta, T. (1988). Testing linearity against smooth transition autoregressive models. *Biometrika, 75*(3), 491-499 .

Miketa, A., & Mulder, P. (2003). Energy-productivity convergence across developed and developing countries in 10 manufacturing sectors .

Mishra, V. (2019). Measuring Technical Efficiency in Healthcare Service: A Case Study .

Mohammad zadeh, p., & Ebrahimi, S. (2014). The Relationship between Energy Consumption and Financial Development in Iran. *Quarterely Energy Economics Review, 9*(39), 77-104. Retrieved from http://iiesj.ir/article-1-339-en.html

Neves, F. d. O., Ewbank, H., Roveda, J. A. F., Trianni, A., Marafão, F. P., & Roveda, S. R. M. M. (2022). Economic and Production-Related Implications for Industrial Energy Efficiency: A Logistic Regression Analysis on Cross-Cutting Technologies. *Energies, 15*(4), 1382 .

OECD ,I. (2016). Energy and air pollution: world energy outlook special report 2016 .

Ogunsola, A. J., & Tipoy, C. K. (2022). Determinants of energy consumption: The case of African oil exporting countries. *Cogent Economics & Finance, 10*(1), 2058157 .

Oluoch, S ,.Lal, P., & Susaeta, A. (2021). Investigating factors affecting renewable energy consumption: A panel data analysis in Sub Saharan Africa. *Environmental Challenges, 4*, 100092 .

Otsuka, A. (2018). Regional determinants of energy efficiency: Residential energy demand in Japan. *Energies, 11*(6), 1557 .

Ozturk, I., & Acaravci, A. (2011). Electricity consumption and real GDP causality nexus: Evidence from ARDL bounds testing approach for 11 MENA countries. *Applied Energy, 88*(8), 2885-2892 .

Rahimy, K., Faraji Dizaji, S., & Assari Arani, A. (2022). The Impact of Renewable Energy Consumption on Social Development in OECD Countries. *Quarterly Journal of Quantitative Economics*, -. doi:10.22055/jqe.2022.39230.2439

Rezitis, A. N., & Ahammad, S. M. (2015). The relationship between energy consumption and economic growth in south and Southeast Asian countries: A panel VAR approach and causality analysis. *International Journal of Energy Economics and Policy, 5*(3), 704-715 .

Sadorsky, P. (2010). The impact of financial development on energy consumption in emerging economies. *Energy Policy, 38*(5), 2528-2535 .

Savari, A., Fatrus, M. H., Haji, G., & Najafizadeh, A. (2020). Asymmetric analysis of the effect of energy consumption and financial development on economic growth in Iran: Application of nonlinear ARDL method. *Quarterly Journal of Quantitative Economics, 17*(3), 69-90. doi:10.22055/jqe.2019.28107.2012

Sineviciene, L., Sotnyk, I., & Kubatko, O. (2017). Determinants of energy efficiency and energy consumption of Eastern Europe post-communist economies. *Energy & Environment, 28*(8), 870-884 .

Sinha, D. (2009). The energy consumption-GDP nexus: Panel data evidence from 88 countries .

Teräsvirta, T. (1994a). Specification, estimation, and evaluation of smooth transition autoregressive models. *Journal of the american statistical association, 89*(425), 208-218 .

Teräsvirta, T. (1994b). Testing linearity and modelling nonlinear time series. *Kybernetika, 30*(3), 319-330 .

Tsay, R. S. (1989). Testing and modeling threshold autoregressive processes. *Journal of the american statistical association, 84*(405), 231-240 .

Uzar, U. (2020). Political economy of renewable energy: does institutional quality make a difference in renewable energy consumption? *Renewable Energy, 155*, 591-603 .

Vafaei, E., Pendar, M., & Masumzadeh, S. (2021). Investigating the Financial Development on Energy Consumption. *Program and Budget Research, 2*(3), 99-115. doi:10.22034/pbr.2021.145872

Wang, S., Li, Q., Fang, C., & Zhou, C. (2016). The relationship between economic growth, energy consumption, and CO2 emissions: Empirical evidence from China. *Science of the Total Environment, 542*, 360-371 .

Yalta, A. T. (2011). Analyzing energy consumption and GDP nexus using maximum entropy bootstrap: the case of Turkey .*Energy Economics, 33*(3), 453-460 .

zaroki, s., & moghadasi sedehi, A. (2021). Energy Consumption in Economic Sectors and Environmental Pollution in Iran with Emphasis on Electricity and Non-Electricity. *Quarterely Energy Economics*

Review, *17*(68), 195-226 .Retrieved from http://iiesj.ir/article-1-1225-en.html

Zhixin, Z., & Xin, R. (2011). Causal relationships between energy consumption and economic growth. *Energy Procedia, 5*, 2065-2071 .