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Investigating the Effect of Economic and Non-Economic Factors on Energy Demand in Iran's Agricultural Sector

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Abstract

Energy demand and the factors affecting it have been growing in importance due to population growth, increased greenhouse gas emissions, and limited energy resources. In this regard, the agricultural sector of Iran shows an increase in the consumption of various energy carriers in this sector in recent years to increase production, employment, and food security. Given the significance of energy resources and environmental protection, the present study aims to investigate the impact of economic and non-economic factors on energy demand in Iran's agricultural sector over the period 1970-2017 using Markov switching-error correction model. The results indicate that the variable of agricultural production in both Markov regimes has a positive and significant effect on energy demand in this sector. The variable of the diversity of agricultural activities affects energy consumption in the agricultural sector positively. In addition, the impacts of human capital and trade liberalization in the agricultural sector on energy consumption in this sector are positive and significant. It is therefore suggested that to manage and optimize energy consumption, appropriate policies should be implemented in this sector to mitigate the environmental pollution and prevent the reduction of agricultural production.

Keywords:
Activity diversity; agricultural sector; energy; human capital; markov switching - error correction

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INTRODUCTION

Energy plays a key role in production processes and economic and social development as a major source of sustainable economic growth in developed and developing countries (Makun, 2015). In recent years, increasing greenhouse gas (GHG) emissions, acid rain, global warming, and climate change have increasingly drawn researchers' and policymakers' attention to the negative effects of increased energy consumption on economies. Since the 1850s, global energy demand has annually grown by about 2.5 percent (Sorrell, 2015). Therefore, improving energy efficiency has been proposed as an important strategy to achieve the goal of sustainable development and energy security in the future and reducing GHG emissions (Marrero & Ramos-Real, 2013). Iran is a country that owns large energy resources and oil reservoirs, huge underground mines, and extensive potential energy resource, but it is known as a country that has put pressure on natural resources and has a high energy consumption rate (Khadem et al., 2014; Yazdanpanahdrou et al., 2017). The abundance of energy resources in this country and the disregard for the concepts of sustainability have further intensified this high energy consumption in Iran (FAO, 2009; International Energy Agency, 2012). Energy is one of the most important factors of production, which was entered into the function of production of important economic sectors, including agriculture, after the industrial revolution and has greatly reduced the share of other factors. The study of energy consumption in the agricultural sector is very important because in recent decades, due the growth of population and increasing demand for agricultural products and food, this sector has become an energy-oriented sector by moving towards mechanization and lack of proper management. Investigating the trend of energy consumption in Iran's agricultural sector shows that during different years, with the increase in production and added value, the consumption of various energy carriers, including petroleum products and electricity has increased (Nasrnia & Esmaeili, 2009). Energy has a high potential to be replaced with other production inputs. The energy consumption of the agricultural sector has further escalated significantly with the advancement of technology in the agricultural sector and the introduction of various energy-efficient equipment in the production processes of this sector (Falahi & Khalilian, 2009).

Several studies have addressed the effects of factors affecting on energy consumption in various economic sectors. Bakhshayesh and Yazdani (2015) estimated the energy demand function in Iran's agricultural sector. They showed that electricity and oil inputs replaced gas and capital and found that oil and gas were more sensitive to price changes. Fang et al. (2017) examined electricity demand in Chinese provinces by advance panel econometric methodologies such as Cup single bond FM estimators and bootstrapped panel Granger causality tests. They showed that human capital had reduced energy consumption. Ilesanmi and Tewari (2017) investigated the dynamic causal relationship between energy consumption, human capital investment and economic growth in South Africa for the period 1960–2015 within the vector error correction model framework. The finding showed that there was a positive and significant relationship between economic growth, human capital, and energy consumption in South Africa. Gharebaghi and Emami Meybodi (2017) studied the factors affecting electricity consumption in the industrial, domestic, and agricultural sectors. In this regard, the electricity demand function in the three mentioned sections was fitted with the ordinary least squares method for the period 1976-2013. The results showed that electricity had not been a strong alternative in any of the three sectors. In a study in China, Salim et al. (2017) investigated the dynamic relationship between human capital and energy consumption using Chinese provincial data over the period 1990–2010. Considering for cross-sectional dependence and parameter heterogeneity across space and over time, they identified a significant and negative human capital–energy consumption relationship in China. The results revealed that the relationship between economic growth and energy consumption was positive. Inglesi-Lotz and Morales (2017) examined the impact of education on energy consumption in developing and developed countries for the period 1980-2013. A unidirectional relationship was found between energy consumption and education. Based on the results, energy consumption is directly related to the education level in developing countries while this relationship is indirect in developed countries flowing from education to energy consumption. Shabanzadeh et al. (2017) addressed the relationship between economic development and the diversity of activities with energy intensity in the agricultural sector. In order to achieve the goal, by using modeling algorithms Fomby, relationship between diversification index, the share of agriculture in GDP and trade liberalization with energy intensity identifying and then in the framework of Johansen-Juselius cointegration model was examined for the period 1981-2012. The results of their study showed that the diversity of activities, trade liberalization and economic development had a positive effect on energy intensity. Farhani and Solarin (2017) examined the relationship between trade liberalization and energy demand in the United States. In their study applied a newly developed LM unit root test based on residual augmented least squares regression under structural break and Bayer–Hanck cointegration approach over a period of 1973–2014. The finding showed that trade liberalization had a positive effect on energy demand. According to Lovarelli et al. (2018), agricultural machinery plays an important role in assessing the sustainability of the agricultural environment and fuel consumption. In addition to processing data from field experiments by evaluating the life cycle, they adopted a model for predicting energy consumption and engine exhaust emissions. Hosseinzadeh Samani et al. (2018) studied energy consumption and the use of alternative fuels in the agricultural sector of Khuzestan. According to the Life Cycle Analysis mode, they stated that energy efficiency in this sector was low and GHG emissions were high. Sanchez-Escobar et al. (2018) showed that in the late twentieth century, new patterns in energy consumption in the agricultural sector emerged in rural Spain. They concluded that by using sustainability models and applying a methodology that combines process analysis, revenue and energy efficiency were increased. Farajian et al. (2018) studied the demand for energy in the agricultural sector using Box–Jenkins methodology for the period spanning from 1988 to 2014. They considered the trend of energy consumption to be increasing. Chen et al. (2019) argued that groundwater extraction in the agricultural sector requires high energy consumption. Based on single-well pumping method, a distributed energy consumption model for groundwater irrigation was proposed and emphasized it is necessary to use water and energy-saving technologies in the agricultural sector. Shahbaz et al. (2019) examined the impact of human capital and the existence of natural resources on energy demand in the United States. They using the bootstrapping autoregressive-distributed lag cointegration approach and the Vector Error Correction Mechanism's Granger causality analysis revealed a feedback effect between education, natural resources and energy demand. Their study showed that education has a negative impact on energy demand,natural resources have a positive impact on energy consumption and a bidirectional causality also exists between economic growth and energy demand in this country. Baz et al. (2019) emphasized the role of energy in the growth of agriculture and the economy in Pakistan. They used time series data from 1971 to 2014 and employed the Non-linear Autoregressive Distributed Lag model and concluded that by attracting foreign investment, the policies of the energy sector could be reviewed. Ziaabadi and Zare Mehrjerdi (2019) investigated the factors affecting energy consumption in Iran's agricultural sector. Using the ARDL-fuzzy method and data from the period 1974-2015, they showed that the share of the agricultural sector and the intensity of energy consumption had a positive effect on energy consumption in the agricultural sector. Ali et al. (2019) studied the environmental impact of energy consumption in agriculture in India and Pakistan using life cycle assessment methodology. They reported that electricity consumption has been increasing and that higher consumption of this type of energy in the agricultural sector has not necessarily led to a cleaner environment in these countries. Sasouli and Jamnia (2019) investigated energy efficiency in Iran's agricultural sector using the hidden cointegration method. They considered price liberalization and efficient use necessary because Iran's per capita energy consumption in the agricultural sector is 3.2 times higher than that of the global sector. Lewandowska-Czarnecka et al. (2019) studied environmental sustainability and energy efficiency in Poland and showed no significant differences between energy and pollution indices before and after EU accession. Tian et al. (2019) used energy data in Chinese agriculture and showed that energy efficiency was influenced by season. Raeeni et al. (2019) tried to empirically identify such relation by using time series econometrics techniques including causality and cointegration tests for the period 1967–2015. Main results confirmed that there was a unidirectional causality that flew from energy consumption to agricultural growth while energy consumption and export were found to have no significant relationship with one another. Chen et al. (2020) addressed the decoupling statuses between energy consumption and economic growth in the agricultural industry of 89 countries where data were available for the 2000-2016 period and reported that only 18 countries have reached strong decoupling. The decomposed factors and corresponding policy implications provided evidence for decision makers of each nation to tailor energy-saving strategies in its agricultural industry.

Extensive studies have been conducted recently on the application of the Markov switching method, some of which are mentioned below. Basher et al. (2016) used Markov-switching models to study the impact of oil shocks on real exchange rates for a sample of oil exporting and oil importing countries. The results revealed that there was regime switching for the effects of oil shocks on real exchange rates. Charfeddine (2017) investigated the effect of factors affecting the ecological footprint in Qatar during 1970-2015- using the Markov switching method - vector error correction. The results show that Markov nonlinear model has higher accuracy than linear models. Nademi and Nademi (2018) to predict crude oil prices for the period 2010-2015, ARIMA and GARCH models were compared with Markov Switching models. The estimation results showed that the semi parametric Markov switching models forecasted the crude oil prices more accurately than the ARIMA and GARCH models. Chen et al. (2019) developed a theoretical framework to analyze the effects of financial factors on fluctuations in nonferrous metals prices and employed the Markov-switching vector auto regression (MS-VAR) model to develop a nonlinear empirical analysis. A new intellectual framework and analysis tool was provided by the conclusions and the nonlinear econometric models that were established by this study to account for the financialization of commodity markets. Alola (2020) analyzed the relationship between the sector performances of states' economies of Saudi Arabia and the dynamics of crude oil prices using Markov switching regression and 2005-2019 data. The findings showed that the return on crude oil prices varies in different regimes. Rahman et al. (2020) dealt with the effect of financial development on economic growth in Pakistan by using the

Markov Switching Model over the period 1980–2017. The results of the two-state Markov switching model confirmed the Schumpeter's view that finance spurs growth. The result revealed that financial development augmented economic growth in both high and low economic growth regimes in Pakistan Sedaghat Kalmarzi et al. (2020) investigated the effect of oil revenues on Iran's economic growth over the period 1971-2017 using a hybrid threshold Markov switching model. The results from the model estimation indicate that oil revenue has a nonlinear and threshold effect on Iran's economic growth regimes. Tehranchian and Abonouri (2020) investigated the effect of oil price fluctuations on the financial instability index during a period of 2009-2018 monthly in Iran using the Markov switching model. The results show that the effect of oil price fluctuations is different in different regimes and different time periods. Ashouri and Rafei (2021) studied in a research study on the causality relationships among the water resources, energy productivity, and air pollution in Iran over 1971-2014 using the Markov-switching vector autoregressive models, they performed a Granger-causality analysis to evaluate the indirect unidirectional relationship between the energy productivity and water resources at different times.

Therefore, considering the importance of energy, this study aims to investigate the impact of economic and non-economic factors on energy consumption in the agricultural sector of Iran for the period 1970-2017 using the Markov switching-vector error correction method.

The novelty of the research is that simultaneously studies the impact of economic and non-economic factors on energy consumption in the agricultural sector. Economic factors directly affect energy consumption and their impact on energy consumption is clearer, while non-economic factors indirectly affect energy consumption through the impact on consumer attitudes and behaviors. On the other hand, the nonlinear Markov Switching-Error Correction Model is employed because it is advantageous over the linear models in the sense that it can measure the effect of factors on energy consumption in different conditions and regimes and so far, no research has been conducted in this field. This method reduces fit error by allowing the fitting of variable coefficients in different regimes, thereby preventing the hiding of data break effects in variable coefficients. Also, it can reveal the coefficient of adjustment of short-term variations to find out the long-term trend, which is useful for policymaking.

METHODOLOGY

Various factors affect the energy demand in various economic sectors, including agriculture (Shahbaz et al., 2016; Shahbaz et al., 2019; Grossman and Krueger, 1991). The experimental model of the energy demand in this study is written using the Cobb-Douglas production function and for capital and energy inventory inputs as Eq. (1):

$$Y=E^{\alpha} K^{\beta} \qquad (1)$$

in which *Y* is agricultural production, *K* is agricultural capital stock, and *E* is consumption in the agricultural sector, and and are elastic demand for energy and capital, respectively,

The conditional demand for energy is in the form of Eq. (2):

$$E=Y(\alpha P_{k}/\beta P_{E})^{\beta} \qquad (2)$$

in which and are the prices of capital and energy, respectively. Eq. (2) can be expanded if there are further variables. Based on the previous studies, including Bakhshayesh & Yazdani (2015), Sasouli & Jamnia (2019), Mulder et al. (2014), Shahbaz et al. (2019) and Yazdani et al. (2017), the economic factors affecting energy consumption in the agricultural sector were identified in the present study to include agricultural production, energy prices, and trade liberalization, and the non-economic factors were identified to include natural resource inventory, human capital, and diversity of agricultural activities.

The final equation of the energy demand function in the agricultural sector is considered as Eq. 3 in the form of a linear logarithm.

$$LE_{t} = \beta_1\ LGDP_t + \beta_2\ LR_t + \beta_3\ LP_t + \beta_4\ LEDU_t + \beta_5\ LENI_t + \beta_6\ LOP_t + \mu_t \tag{3}$$

in which *E* represents energy consumption of the agricultural sector, *GDP* represents the production of the agricultural sector, *R* represents natural resources as a percentage of GDP, *P* represents energy prices in the agricultural sector, *EDU* represents human capital index (education budget), *OP* represents trade liberalization indicator (total exports and imports of the agricultural sector) and represents the index of the diversity of activities in the agricultural sector. is estimated as follows:

$$ENI = \sum_{i=1}^{N} p_i \times log(\frac{1}{p_i}) \tag{4}$$

in which *N* is the number of production activities and is the share of each activity in the total production activities.

Given the diversity of production activities in the agricultural sector of Iran (horticultural, livestock, agricultural and fishery products), the criterion of the share in the gross income of each activity was used to calculate the diversity index (Hart, 1971; Shabanzadeh et al., 2017). To estimate Eq. (3), the annual data of 1970-2017 of Iran's agricultural sector have been used. Data on agricultural production, education, diversity of activities, world trade, natural resources (as a percentage of GDP) were collected from the World Bank, and data on energy consumption and its price in the agricultural sector of Iran were collected from the Iranian energy balance sheet.

Markov switching- error correction model (Ms-Ecm)

The Markov Switching model is nonlinear method. The nonlinear models assume that the variable behaves differently in different conditions. This model employs probabilities to classify the time-series variables and the relations of the variables among two or more regimes and calculates the likelihood of transfer from one regime to another or staying in the existing regime. One advantage of the Markov Switching method over the other methods is distinguishing the endogeneity of the observations of a variable and distinguishing the endogeneity of the relations among the observations of variables. In this respect, the issues of dummy variables and structure failure are not relevant. It is also possible to predict the variations of the variables from one regime to another (Zarei et al., 2020).

The Markov switching-vector error correction method was used to derive the energy demand function in Iran's agricultural sector and to investigate the factors affecting its demand. This method is superior to the vector error correction model as it can measure the effects of different factors in different regimes.

The general form of the Markov switching-error correction model is (Charfeddine, 2017) as follows:

$$\Delta Y_t = \alpha ECM_{t-1,s_{t-1}} + \sum_{i=1}^{\gamma} \Gamma_j \Delta X_{t-i} + \sum_{j=1}^{s} \pi_j \Delta Y_{t-j} + u_t \tag{5}$$

$$ECM_{t-1,,s_{t-1}} = (Y_{t-1} - \beta_{st-1} X_{t-1} - \mu_{st-1}) \tag{6}$$

in which α is the long-run adjustment, X_t is the vector of independent variables, Y_t is the dependent variable, : is the first-order difference, S and are the log of the independent and dependent variable in short-term, respectively, and S_t a dummy variable with values 0 and 1 in Markov two regimes:

$$s_t \begin{Bmatrix} 1 \ \ with\ probability\ p_{11} \\ 2 \ \ with\ probability\ p_{22} \end{Bmatrix} \tag{7}$$

where

$$p_{11} = P[s_t = 1|s_{t-1} = 1]$$
$$p_{22} = P[s_t = 2|s_{t-1} = 2]$$
$$\sum_{i=1}^{2} p_{ij} = 1 \quad for \quad j = 1,2.$$

Based on the explanations, intercept and slope coefficients can be measured based on the Markov-switching method:

$$\mu_{st} = \mu_1 + (\mu_2 - \mu_1)(s_t - 1)$$
$$\beta^{st} = ((\beta_1^1, \beta_1^2), (\beta_2^1, \beta_2^2), \dots, (\beta_k^1, \beta_k^2)) \tag{8}$$

where K represents the number of independent variables of the model and β is regarded as the slope of independent variables in different regimes. In this study, Gauss 15 and Matlab software packages were used to estimate the Ms-ECM model. These software packages provide the conditions for simultaneous change in the intercept and slope of each of the independent variables in the energy demand model. To determine the number of model regimes, the significance level of the models fitted with different number of regimes and the significance of transfer matrix coefficients.

The final relationship used is:

$$LE_t = \mu_{st} + \beta_1^{st} LGDP_t + \beta_2 LR_t + \beta_3 LP_t + \beta_4 LEDU_t + \beta_4 LEDU_t + \beta_5 LENI_t + \beta_6 LOP_t + \hat{\varepsilon}_t$$

Also, in time-series data, it is first necessary to examine the stationarity of the variables, which was here checked by the augmented Dickey-Fuller (1979) test. Then, the long-term relationship between the variables was investigated using the Markov-switching method. The advantage of the Markov-switching method is that it avoids hiding the effects of regime change on the coefficients of the model variables. The Granger-causality test was used to investigate the causal relationship between the variables, and the set of the residues of the long-term series was called ECT1t.

$$ECT_{1t} = (LE_t - \beta_1^{st} LGDP_t - \beta_2 LR_t - \beta_3 LP_t - \beta_4 LEDU_t - \beta_5 LENI_t - \beta_6 LOP_t - \mu_{st}) \tag{10}$$

Then, the short-term relationship was estimated using Eq. (11).

$$\begin{pmatrix} \Delta LE_t \\ \Delta LRGDP_t \\ \Delta LR_t \\ \Delta LP_t \\ \Delta LEDU_t \\ \Delta LENI_t \\ \Delta LOP_t \end{pmatrix} = \begin{pmatrix} \theta_1 \\ \theta_2 \\ \theta_3 \\ \theta_4 \\ \theta_5 \\ \theta_6 \\ \theta_7 \end{pmatrix} + \sum_{j=1}^{k} \begin{pmatrix} c_{1,1,j} & \cdots c_{1,7,j} \\ & \cdot \\ & \cdot \\ & \cdot \\ c_{7,1,j} & \cdots c_{7,7,j} \end{pmatrix} \begin{pmatrix} \Delta LE_{t-1} \\ \Delta LRGDP_{t-1} \\ \Delta LR_{t-1} \\ \Delta LP_{t-1} \\ \Delta LEDU_{t-1} \\ \Delta LENI_{t-1} \\ \Delta LOP_{t-1} \end{pmatrix} + \begin{pmatrix} \lambda_1 \\ \lambda_2 \\ \lambda_3 \\ \lambda_4 \\ \lambda_5 \\ \lambda_6 \\ \lambda_7 \end{pmatrix} ECT_{1t-1} + \begin{pmatrix} u_{1,t} \\ u_{2,t} \\ u_{3,t} \\ u_{4,t} \\ u_{5,t} \\ u_{6,t} \\ u_{7,t} \end{pmatrix} \tag{11}$$

Therefore, using Eq. (10) and (11), the long-term and short-term relationship between the variables will be fitted and their coefficients and significance will be discussed.

RESULTS

In this step, unit root testing of variables was performed by using Augmented Dickey-Fuller (Dickey & Fuller, 1979) test. The results in Table 1 indicate that none of the variables have stationary data. But, all variables have become stationary with a single differentiation.

The results of the Dickey-Fuller test indicate that all variables are stationary of the once difference, I (1).

It should be noted that the likelihood ratio test for determining linearity or nonlinearity was performed (Hansen, 1992; Asgharpour et al., 2010), according to which the model is nonlinear. In the following, the long-run relationship between variables is investigated using the Markov switching- error correction model.

The results of the long-run relationship between all variables are reported in regimes 1 and 2 when only intercept and the slope coefficient of agricultural production are switched (values in parentheses are standard deviations).

Table 1
Unit Root and Stationary Test Using the Augmented Dickey-Fuller Test

Variable	Level	Critical value 5%	First difference	Critical value 5%	Result
LE	-2.553	-2.931	-6.203	-2.933	I(1)
LGDP	-1.782	-2.931	-7.259	-2.933	I(1)
LR	-2.130	-2.931	-6.760	-2.933	I(1)
LP	-2.268	-2.931	-6.288	-2.933	I(1)
LEDU	-2.078	-2.931	-5.834	-2.933	I(1)
LENI	-0.791	-2.931	-5.739	-2.933	I(1)
LOP	-2.470	-2.931	-7.184	-2.933	I(1)

$$LE_t = -5.337 + \underset{(0.1251)}{0.319LGDP_t} + \underset{(0.1125)}{0.095\,LR_t} - \underset{(0.0421)}{0.008\,LP_t} + \underset{(0.146)}{0.112\,LEDU_t} + \underset{(0.0477)}{} \underset{(0.0366)}{0.116\,LENI_t} + \underset{(0.0242)}{0.086\,LOP_t} + \hat{\varepsilon}_t \quad (12)$$

If $S_t = 1$
and

$$LE_t = -4.086 + \underset{(0.1153)}{0.376LGDP_t} + \underset{(0.0437)}{0.095LR_t} - \underset{(0.0421)}{0.008\,LP_t} + \underset{(0.146)}{0.112\,LEDU_t} + \underset{(0.0477)}{} \underset{(0.0366)}{0.116\,LENI_t} + \underset{(0.0242)}{0.086\,LOP_t} + \hat{\varepsilon}_t \quad (13)$$

If $S_t = 2$

and the transfer matrix between the two regimes is:

$$\hat{P} = \begin{pmatrix} p_{11} & p_{12} \\ p_{21} & p_{22} \end{pmatrix} = \begin{pmatrix} 0.93(0.01) & 0.07 \\ 0.05 & 0.95(0.00) \end{pmatrix} \quad (14)$$

According to the results of the transfer matrix, the probability of stability is 0.93 in regime 1 and 0.95 in regime 2 (p_{22}). The probability of transition from regime 1 to regime 2 and vice versa is 0.07 and 0.05, respectively (p_{12},p_{21}). Also, the high level of significance of the stability probability of regimes 1 and 2 indicates that each regimen is stable for a sufficient period of time, which confirms the reliability of the results obtained from the model (Zarei et al., 2020).

The results of Eq. 12 and 13 indicate that the production of the agricultural sector has a positive and significant effect of 0.319 and 0.376 in the first and second regimes on energy consumption in this sector. The energy price variable in the agricultural sector has a negative (-0.008) and no significant effect on energy consumption in this sector. The energy price variable is one of the main variables in energy demand in all countries; however, due to the low price of energy in Iran and its unreality (nominal price), the coefficient of this variable is not significant in this study. This means that an increase in the nominal price of energy has not reduced its consumption.

Liberalization variable has a positive and significant effect of 0.086 on energy consumption in Iran's agricultural sector. This means that if trade liberalization increases by 1 percent, energy consumption will increase by 0.086 percent.

Index of activity diversity has a positive and significant effect (0.116) on energy consumption. Diversification of activities means a change in product selection and use of inputs based on market drivers. An increase of 1 percent in the diversity of activities in the agricultural sector will increase energy consumption in this sector by 0.166 percent. The diversity of activities in the agricultural sector can affect energy consumption in this sector by providing inputs and outputs assistance. The coefficient of variable human capital concerning energy demand is 0.112, which indicates the positive effect of education and human capital on energy consumption. In other words, with the increase of human capital and education, energy consumption in the agricultural sector has increased, because increasing the education of people has increased the use of mechanization and energy-intensive machinery in this sector.

The presence of rich natural resources has also increased energy consumption in the agricultural sector so that a 1 percent increase in natural resources has increased energy consumption by 0.095 percent. The existence of natural resources and their increase has stimulated economic growth and energy consumption growth and with increasing agricultural production, energy demand has increased.

ECM coefficient or error correction factor in the Markov switching-vector error correction method indicates that, in each period, the short-term to long-term deviations are adjusted by -0.0421 (Table 2). The results of the estimated value of transfer probability, and their level of statistical significance indicates the validity of the Ms-Ecm Method (Charfeddine, 2017).

DISCUSSION

According to population growth forecasts, energy demand will increase in the future and energy security will be increasingly considered. In the last decade, limited energy resources and environmental pollution have made energy consumption more important for all countries. In Iran, the agricultural sector has a smaller share in final energy consumption than other sectors but in recent years, energy consumption in this sector has always increased. The great importance of energy resources has necessitated the exploitation of these resources in accordance with environmental laws and sustainable economic and social development and the study of factors affecting energy consumption. Considering the positive effect of agricultural production variable on energy consumption in this sector, it can be concluded that the perishability of agricultural products has caused farmers to have time constraints in harvesting, processing, storage, transportation, and marketing of their products. Therefore, to reduce crop waste, farmers have to control and compensate for the low opportunity and perishability of crops to a large extent by putting pressure on energy consumption in processing and storage. It should be noted that in the agricultural sector, there is very little alternative between energy inputs and other inputs of production, including labor and capital. Water extraction in agriculture and groundwater abstraction are other important factors that force farmers to use more energy in this sector. With the advancement of technology, technology change, and the use of energy-based machinery and equipment in many agricultural sec-

Table 2
Short-term Coefficients of Energy Demand

MS-ECM	
Variable	**Coefficient**
ecm(-1)	-0.0421**
D(LE(-1))	0.588***
D(LGDP(-1))	0.356**
D(R(-1))	0.135***
D(P(-1))	0.216
D(LEDU(-1))	-0.243*
D(LENI(-1))	-0.114**
D(LOP(-1))	0.482*
C	-0.0359*

*, **, *** Significantly at the level of 10%, 5% and 1%, respectively

tors and increasing the level of mechanization, the use of energy inputs has increased, which is consistent with the studies of Farhani & Solarin (2017) Shahbaz et al. (2019), Salim et al. (2017) and Nasrnia & Esmaeili (2009).

Energy price in Iran is relatively low and due to the lack of suitable substitutes for energy in the agricultural sector, increasing energy prices has not had a significant effect on reducing energy consumption. This result can be confirmed by examining the trend of energy consumption in the agricultural sector of Iran; especially in recent years, electricity consumption has increased significantly. The reason for the insignificance of the price coefficient on energy consumption is that the growth of value-added in the agricultural sector due to changes in prices and inflation has been more than the growth of nominal energy prices. With the gap between nominal and real energy prices, despite the increase in prices, a decrease in energy consumption is not observed in this sector. It should be noted that energy in the agricultural sector is an essential input that has no suitable alternative. Excessive energy resources in the country and policies of easy and cheap access to energy and strong price support in all economic sectors of Iran, especially in the agricultural sector, have hindered the understanding of the importance of energy by consumers. In recent decades, energy costs have not played an important role in the decision-making and selection of technology, machinery, and equipment in the agricultural sector. Therefore, farmers have used machines and equipment that have low efficiency and energy efficiency, which means less investment and higher operating costs. This result is confirmed by Shakibaei and Ahmadlou (2011), Sasouli and Jamnia (2019), Farajian et al. (2018), Ziaabadi and Zare (2019).

The positive coefficient of the trade liberalization variable in the agricultural sector indicates that the increase and development of economic activities due to the increase in international trade, liberalization, and reduction of trade barriers has increased demand for energy, which allows developing countries to import advanced technologies and finally reduce the intensity of energy consumption. In Iran's agricultural sector, energy demand has continued to increase with increasing agricultural production and liberalization. Liberalization can increase labor productivity and motivate more innovation, resulting in economic prosperity and increased energy consumption. Due to the low prices of agricultural products in the country, the devaluation of the national currency, increased exports and trade of agricultural products, and increased foreign demand for agricultural products in the country, energy consumption has increased in Iran's agricultural sector. This result is consistent with Farhani and Solarin's (2017) study.

The diversity of agricultural activities can reduce consumption or reduce the intensity of energy consumption in the agricultural sector if it results in using advanced technologies to a greater extent or saving energy. The positive coefficient of the effect of diversity of activities in the agricultural sector on energy consumption indicates that despite the diversity of agricultural, livestock, horticultural, and fishery activities, input and output assistance and possible flexibility have not been created and the production and management inputs have not been fully used in this sector. Therefore, the diversity of agricultural activities has also increased energy consumption due to an increase in agricultural activities. Although increasing the diversity of activity in Shabanzadeh et al. (2017) and Yazdani et al. (2017) Studies had a negative effect on energy efficiency in the agricultural sector of Iran, Renting et al. (2008) reported its positive effect on energy consumption.

Human capital and education have had a positive impact on energy consumption in Iran's agricultural sector. Human capital can innovate and improve the production process and have a positive or negative effect on energy demand. On the one hand, education leads to an advancement of technology and more efficient use of resources and increases environmental adaptation. On the other hand, it can increase production opportunities and increase energy consumption by increasing the area under cultivation and increasing the level of agricultural activities. If in the process of increasing human capital and education, people seek to increase energy efficiency and can use energy-saving technologies in the production process, energy consumption will also decrease. But in Iran, with increasing the level of education due to insufficient attention to energy efficiency and productivity and the lack of appropriate environmental policies, energy consumption has increased for more production over the studied period. This result is consistent with Fallahi et al. (2009) and Inglesi-Lotz & Morales (2017) but inconsistent with Fang & Chen (2017) and Salim et al. (2017). The main reason for the inconsistency of the results is the difference in the study area and in access to energy resources.

The positive effect of natural resource inventory on energy consumption shows that the existence of rich natural resources stimulates economic growth and increases production in all economic sectors, including agriculture. In Iran, the abundance of available natural resources has increased production incentives, which has ultimately increased energy consumption in the agricultural sector due to the energy-intensive production activities of this sector, which has been confirmed by Shahbaz et al. (2019) and Khadem et al. (2014).

CONCLUSION

Considering the pivotal role of energy in the growth of economic sectors, including the agricultural sector, this study was conducted to investigate the impact of factors affecting energy consumption in the agricultural sector of Iran. Therefore, the literature was reviewed to identify the economic and non-economic factors affecting energy consumption in the agricultural sector. Then, after the unit root test and static study of the model variables, the nonlinearity model versus its linearity test was performed, which showed the existence of a nonlinear relationship between the variables. Finally, the long-term and short-term relationship between the model variables of the energy demand function model in the agricultural sector was estimated using the Markov switching method - vector error correction and data from 1970 to 2017. The nonlinear Markov switching method has the advantage that it can measure the effects of different factors on environmental degradation in different regimes and reduce the error. If the relationship between these variables is not determined correctly, the results will be unreliable.The results indicate that the variable of agricultural production has a positive and significant effect on energy consumption in this sector. In the studied years, with an increase in agricultural production, energy consumption has increased.

The energy price variable in the agricultural sector has not had a significant effect on energy consumption in this sector, which has been expected following the application of energy technology. Trade liberalization in the agricultural sector has increased energy consumption in this sector because of the diversity of climate and the comparative advantages of the agricultural sector in many export products, energy consumption has also increased for more production and more trade. The diversity of activities in the agricultural sector has had a positive effect on energy consumption in this sector. In Iran's agricultural sector, increasing diversity has not been accompanied by an increase in the use of energy-saving technologies, which has increased energy consumption of this sectorThe effect of natural resources inventory on energy consumption in Iran's agricultural sector has been positive and significant. This means that due to the abundance of natural resources, energy consumption has increased. Education in the agricultural sector has increased the incentive to produce more profit. The positive impact of human capital on energy consumption in the agricultural sector has shown that increasing awareness and the ability to use modern but energy-intensive technologies to increase production has increased energy consumption.

The existence of price and non-price protection policies has also led to inefficient use of energy, environmental degradation, and air pollution. The results suggest that it is necessary to reduce energy consumption and protect the environment (both of which are unavoidable goals). It is imperative to adopt policies to increase energy efficiency to reduce energy consumption in the agricultural sector without harming the production, economy, and food security of the country while protecting the environment. It should be noted that agricultural activities as one of the most important inputs to production requires energy consumption. According to the structure of Iran's agricultural sector, adopting a policy of increasing energy prices in order to save and optimize its consumption alone will not be able to solve the problems. Therefore, it is suggested that non-price policies, such as the use of advanced technology, be used alongside energy pricing policies. Human resource training should be prioritized to improve energy efficiency and productivity. Since liberalization has had a positive effect on increasing energy consumption and demand, products should be exported in which the agricultural sector has a competitive advantage in production and trade. It should be noted that the agricultural sector has an important role in employment, currency exchange, food security, and poverty reduction in the country. Improper implementation of policies to reduce energy consumption may lead to reduced production, and this sector will face many problems in achieving the goals of the country's macroeconomy.

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