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RESEARCH PAPER

The effects of policy fluctuations on energy indices in Iran's agriculture sector

Vida Aghamohseni Fashami[1], Reza Moghaddasi[1], Amir Mohammadinejad[1], Hossein Bakhoda[2]

1 *Department of Agricultural Economics, Extension and Education, Science and Research Branch, Islamic Azad University, Tehran, Iran*
2 *Department of Agricultural Mechanization, Science and Research Branch, Islamic Azad University, Tehran, Iran*

Corresponding author: Reza Moghaddasi (r.moghaddasi@srbiau.ac.ir)

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Abstract

Energy is one of the primary factors in production and simultaneously one of the principal commodities. In recent years, the significance of strategic planning in optimizing energy consumption has increased. By examining energy indicators and the impact of various economic policies on them, it is possible to attain a comprehension of past conditions and a picture of the future in different energy sectors. The data spanning from 1947 to 2019 were used through a Non-Linear Autoregressive Distributed Lag (NARDL) for analyzing non-linear effects of policy instability on energy indicators in the agricultural sector of Iran. The results indicated an association among the variables, wherein positive fluctuations in agricultural value-added, with a coefficient of 0.13, and conversely negative fluctuations with a coefficient of -0.09, significantly affected long-term energy consumption. It is notable that the second coefficient lacked statistical significance. Additionally, the asymmetrical effects of other variables on energy consumption and productivity in agricultural practices was confirmed.

Keywords

Policy fluctuations, Energy productivity, Energy consumption, Agriculture, Iran

Introduction

Extensive attention has been directed towards energy planning globally, a matter stemming from the period of oil price surges in the 1970s. Extensive studies on models implementing macro-level energy management policies have been conducted worldwide. The assessment of the impact of executing these policies and programs on energy management plays a pivotal role in measuring their effectiveness and enhancing energy indicators within each country's energy system. The oil crisis and countries' dependence on fossil fuels such as oil and natural gas have heightened the focus on energy policy-making and planning. Studies in energy economics have underscored the critical importance of various energy carriers in meeting the needs of different economic sectors and households. Energy carriers like petroleum products, along with natural gas and electricity, wield significant influence on the development of economic activities.

Recently, due to increased production in the agricultural sector, types of energy consumables have changed along with escalated energy consumption. Given such issues and the imperative to enhance productivity and reduce energy consumption, energy management is a crucial endeavor. Understanding the consumption patterns within each sector is the initial step in energy management. Essential tools for this understanding include energy economic indicators. Analyzing and computing these indicators not only provides insights into the performance status of various economic sectors within the energy domain but also serves as a means to identify and direct consumption patterns in different economic sectors.

Broadly, economic policies encompass a set of demand and supply side policies within an economy. Governments employ these policies to ensure macroeconomic stability, increase employment, and reduce inflation. They utilize monetary, fiscal, and income policy tools. Examining the degrees of uncertainty regarding the outcomes of economic policies can lead to a particular form of economic stabilization policy (Branson 1997). To control energy consumption in countries, typically two sets of policy tools are employed. The first set includes market-based tools (such as taxes, subsidies, and tariffs). The second set comprises regulatory tools (such as rationing, allocation, licenses, and so forth). Energy, being one of the primary factors of production and a crucial commodity, holds a significant position in the development and growth of countries. Inappropriate energy consumption negatively impacts climatic conditions, emphasizing the necessity for optimal energy consumption. This matter holds doubled importance in Iran and its economy due to the extensive availability of energy resources.

Undertaking any action for optimal energy consumption necessitates an understanding of prevailing conditions and comprehension through statistics and information. By considering the statistics provided by the Ministry of Energy, two notable points emerge: Firstly, Iran's energy consumption exceeds the average of OPEC and Middle Eastern countries. Secondly, Iran's energy productivity falls below the average of OPEC and Middle Eastern nations. Hence, there is an essential need for serious measures to bring domestic indicators closer to international standards. In this context, two groups of policies are programmable and implementable: price policies and non-price policies. For instance, targeted subsidy laws represent a price policy, while enhancing energy consumption efficiency represents a non-price policy.

Energy economic indicators stand among the foremost methods for assessing energy consumption conditions. Identifying these indicators within each economic sector not only enables inter-sector comparisons but also provides insights into historical energy consumption trends and the ability to forecast future energy conditions. By analyzing the outcomes derived from calculating these indicators, a more comprehensive understanding of each sector's performance in this domain can be obtained. This, in turn, paves the way for the development of more effective long-term strategies and planning to improve energy consumption patterns. Primarily, the most crucial energy economic indicators employed to gauge energy consumption levels and conditions for economic activities include energy efficiency, final energy consumption, energy productivity, and energy intensity.

Energy productivity refers to the reduction of energy utilized in producing goods and services. Analogous to labor and capital productivity, energy productivity measures the amount of energy used in delivering services and goods relative to inputs. This indicator is derived by dividing the value of production by the quantity of energy consumed. National energy productivity is calculated by dividing the gross domestic product by the total energy consumption. Uncertainty pertains to the lack of assurance concerning probable future events that exists in the minds of consumers, managers, and policymakers. This uncertainty also extends to the path of gross domestic product growth, enterprise growth rates, and non-economic events such as climatic changes (Bloom 2014). Economic policy uncertainty is defined as a lack of stability, usually measured through deviations in economic indicators such as inflation rates, increases in GDP, money supply, domestic credit growth, and government budget deficits (Baker et al. 2016). When policymakers face situations of uncertainty, they are essentially dealing with an objective function and at least one constraint. Hence, the challenge for policymakers lies in navigating uncertain and unknown factors. This uncertainty stems from the governing behavioral rule that dictates the relationship between economic variables. Alongside the objective function, there exist associated structures and limitations. Policymakers strive to create optimal conditions for the primary objective, which might encompass maximizing economic, social, cultural, and political welfare (Nili 2013). Energy intensity is influenced by pricing policies and governmental measures, such as regulated fuel pricing, urban expansion, crude oil exports and petroleum imports, electricity exchange agreements with neighboring countries, gas contracts with regional nations, climatic conditions, industrialization, and greenhouse gas expansion. Due to uncertainties in pricing and monetary policies, energy intensity becomes subject to uncertainty. Therefore, the identification of sources of uncertainty could assist in planning to reduce energy intensity in the country. Uncertainty in economic policies may lead to increased energy consumption intensity and negligence towards productivity improvement processes, technological updates in the energy sector, and reversed demand for energy carriers in Iran. Taxes not only serve as a means to fulfill governmental financial needs but also hold significant importance as a policy tool. As a fiscal instrument, taxes enable governments to accomplish three critical objectives: fair income distribution, economic stability, and resource allocation. They stand as an economic tool allowing government intervention in markets when necessary. Among the primary control instruments at national borders is the customs tariff, which applies to goods and services crossing country borders. Import tariffs are the most common form and are utilized for the purposes of production, revenue, and control (Fathi 2002).

Uncertainty in economic policies directly has a positive effect on energy consumption in the short and long term (Moradi et al. 2021). Reducing trade policy uncertainty reduces energy intensity (Yang and Hong 2021). Export diversification, including product diversification, aided in reducing energy intensity in OECD countries from 1990 to 2015 (Bashir et al. 2020).

Imports promoted the dissemination of international technology and led to a reduction in energy intensity in importing countries (Huang et al. 2017). Uncertainty of macroeconomic policies has a negative effect on energy productivity (Wang et al. 2023). Financial development and economic growth increase energy consumption (Shahbaz et al. 2012; Islam et al. 2013; Sadeghpoor et al. 2018). GDP growth increases renewable energy consumption (Al-Mulali et al. 2013). Economic growth causes the growth of energy consumption, both in the short term and in the long term (Ang 2008). Economic growth and trade openness have a positive impact on energy consumption, but financial openness has a negative impact (Koengkan 2018). The increase in coal consumption shows an increase in real GDP, and energy acts as an important driver of China's economic growth (Jin et al. 2018). Human capital, energy prices, income (GDP), eco-innovation and energy productivity are important factors that an increase in them enhances renewable energy consumption (Li et al. 2020). A growing number of studies indicate that trade (export and import), production and trade liberalization have a positive effect on energy consumption and increase it (Vahidi 2004; Welsch and Ochsen 2005; Cole 2006; Kahral et al. 2008; Armen et al. 2010; Sadorsky 2010, 2011; Halicioghlu 2011).

The review of empirical studies indicated a lack of specific research regarding the impact of policy fluctuations on energy indicators, especially in Iran's agricultural sector. Consequently, this paper seeks to evaluate the impact of policy fluctuations on energy indicators in Iran's agricultural sector using the Nonlinear Autoregressive Distributed Lag (NARDL) econometric method.

Given the general omission of the impact of policy fluctuation variables on energy indicators, particularly in Iran, from most studies concerning the relationship between energy consumption and key economic variables, this study endeavors to thoroughly examine the impact of variables as influential factors on energy indicators in Iran's agricultural sector over a 40-year period.

Materials and methods

One of the dynamic models used to uncover the relationship between dependent and independent variables is NARDL. The primary feature of these models is their capacity to estimate both short-term dynamics and long-term relationships between model variables. Additionally, researchers can determine the number of time periods required for an introduced shock to adjust the model (Pesaran et al. 2001) demonstrated that when a cointegration vector is obtained through using least error squares on an ARDL method, not only the least error estimator has a normal distribution but also has a higher performance and less bias with smaller sample sizes. Standard distributed lag regression models have the following characteristics:

- Identification of long-term cointegration relationships between variables.
- The capability to test both linear and nonlinear cointegration long-run relationships between model variables.
- Ability to distinguish and measure both short-term and long-term effects between estimated variables and their measurement. The notable aspect of these models in comparison to vector error correction models, which possess these three characteristics, is the absence of over-multiplication of the model parameters.
- Unlike other error correction models requiring the cointegration ranks of their variables to be identical, in this model, the equality of cointegration ranks is not a necessity, providing flexibility in variable inclusion.

In this model, the long-term effect between variables will be directional towards either an increase or decrease in magnitude. However, when the effects of increasing or decreasing are asymmetric between variables, the model introduced by (Shin et al. 2014) should be utilized. In NARDL model proposed by (Shin et al. 2014), the short-term and long-term effects are calculated asymmetrically.

In this model, the explanatory variable X_t is divided into two positive variables (ΔX_t^-) and (ΔX_t^+), which are defined as follows:

$$x_t^+ = \sum_{j=1}^{t} \Delta x_j^+ = \sum_{j=1}^{t} \max(\Delta x_j.0) \quad (1)$$

$$x_t^- = \sum_{j=1}^{t} \Delta x_j^- = \sum_{j=1}^{t} \max(\Delta x_j.0) \quad (2)$$

To delineate the long- and short-term asymmetric relationships in ARDL framework, the general form of NARDL models is expressed as follows.

$$\Delta y_t = \mu + p_y y_{t-1} + p_x x_{t-1} + \sum_{i=1}^{r} \alpha_1 \Delta y_{t-1} + \sum_{i=0}^{s} (\beta_i^+ \Delta x_{t-j}^+ + \beta_i^- \Delta x_{t-j}^-) + \varepsilon_t \quad (3)$$

The superscripts (+) and (-) in the second equation lead into the separation of effects into two groups. The asymmetric long-term relationship is obtained through p^- and p^+, while the asymmetric short-term relationships are derived from β^+ and β^-. On the one hand, the short-term analysis considers the impact of the average change in the exogenous variable on the endogenous variable. On the other hand, the long-term analysis signifies the time response and the speed of adjustment towards the long-term equilibrium. The symmetric long-term effects were examined using the Wald test under the assumption of $p^+ = p^-$. The long-term coefficients were obtained through positive and negative changes in the form of $L^+ = -p_x^+/p_y$ and $L^- = -p_x^-/p_y$, signifying the magnitude of the long-run impact. The short-term adjustment of the dependent variable concerning positive and negative differences in the independent variable is determined by parameters β^+ and β^-. Similarly, the test for symmetric short-run relationships can employ the Wald test under the assumption of $\sum_{i=0}^{s} \beta_i^+ = \sum_{i=0}^{s} \beta_i^-$. The second term in the first equation will be equal to the long-term equation when the null hypothesis of symmetrical long-run and short-run relationships is not rejected. The non-rejection of either the long-run or short-run relationships leads to a long-term cointegration

NARDL in the third model and also a short-term NARDL No.*, which are:

$$\Delta y_t = \mu + p_y y_{t-1} + p_x x_{t-1} + \sum_{i=1}^{r} \alpha_i \Delta y_{t-1} + \sum_{i=0}^{s} \left(\beta_i^{+} \Delta x_{t-i}^{+} + \beta_i^{-} \Delta x_{t-i}^{-} \right) + \varepsilon_t \quad (4)$$

$$\Delta y_t = \mu + p_y y_{t-1} + p_x^{+} x_{t-1}^{+} + p_x^{-} x_{t-1}^{-} + \sum_{i=1}^{r} \alpha_i \Delta y_{t-i} + \sum_{i=0}^{s} \left(\beta_i \Delta x_{t-i} \right) + \varepsilon_t \quad (5)$$

Within the NARDL framework, the asymmetric response of the dependent variable to positive and negative changes in the independent variable is calculated as follows:

$$m_h^{+} = \sum_{j=0}^{h} \frac{\partial y_{t+j}}{\partial x_t^{+}} \text{ and } m_h^{-} = \sum_{j=0}^{h} \frac{\partial y_{t+j}}{\partial x_t^{-}} \quad (6)$$

With $h \to \infty$, it leads to $m_h^{+} \to L^{+}$ and $m_h^{-} \to L^{-}$: where $L^{+} = -p_x^{+}/p_y$ and $L^{-} = -p_x^{-}/p_y$ are long-term asymmetrical relationships in the model.

The variables and data in this research included the agricultural sector in Iran, and no qualitative sample was carried out. The required information from the period 1967 to 2019 has been collected from official sources such as the Central Bank of Iran, Iran's Ministry of Energy, the World Bank's website, and others. The data consisted of variables related to agricultural value added, agricultural exports, and energy consumption in the agricultural sector, and trade openness of agricultural sector for Iran.

Table 1. Variables, symbols and data sources used in the research.

Variables	Symbol	Unit (Agricultural sector)	Data Resource
Trade openness	TO	exports plus imports as percent of GDP	World Bank
Energy consumption	AEC	Million barrels of crude oil equivalent	Iran's Ministry of Energy
Value Added	AVA	At the base price - Billion Rials	Central Bank of Iran
Export	AEX	Million dollars	Central Bank of Iran
Energy Productivity	AEP	Value Added/ Energy consumption	Calculated by Authors

Results and discussion

Given the government's policies impacting energy production and consumption, this paper aimed to investigate the influence of political fluctuations on energy indices in Iran's agricultural sector. Considering the time series nature of the variables and to avoid any errors in modeling, the degree of variables' cointegration needed to be established. Hence, common and widely used tests, including Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP), were employed. However, considering criticisms of these two tests related to their disregard for data breaks, the Zivot-Andrews (ZA) test was added to the suite of tests. This selection was made due to the presence of intermittent breaks (shocks) in the research variables. The obtained results are observed in Table 2.

Table 2. The results of the Phillips-Perron stationarity test.

Variable	ADF		pp		ZA			
	Level	First difference	Level	First difference	Level	Break	First difference	Break
AEC	-1.05	-5.22***	-1.06	-4.94***	-1.11	1366	-4.97***	1369
AEP	-1.54	-4.32***	-1.52	-4.86***	-1.56	1387	-4.63***	1387
AVA	-1.02	-4.53***	-1.23	-5.26***	-1.48	1387	-5.68***	1384
AEX	-1.21	-4.84***	-1.11	-4.61***	-1.30	1391	-5.26***	1394
TO	-0.89	-4.38***	-1.01	-4.59***	-1.16	1390	-4.64***	1392

Note: *** refer to sig. level of 1%.

It is evident that all variables possess a unit root and are stationary at first differences. Therefore, all three tests suggested a degree of cointegration equal to one or I(1), while the presence of breaks in certain years was confirmed. This finding might establish the initial mindset favoring the superiority of the nonlinear model. For a more thorough examination, the next step involved testing for the presence of non-linear relationships among the variables. Upon confirmation of this characteristic, it is necessary to employ non-linear (time-dependent) models to estimate the variable relationships, as the use of linear models would be misleading. The most important and commonly used test in this regard, introduced by (Brock et al. 1996), is the BDS test. This test is non-parametric and belongs to the Portmanteau test group. Table 3 illustrates the obtained results.

Table 3. The results of the bound test.

Variable	AEC	AEP	AVA	AEX	TO
Statistic					
M2	12.65***	7.15***	11.32***	13.63***	8.32***
M3	12.45***	7.63***	11.31***	13.98***	7.09***
M4	13.63***	8.36***	10.66***	14.15***	8.25***
M5	15.22***	9.16***	12.21***	15.64***	9.63***
M6	17.46***	11.17***	14.35***	16.49***	10.22***

Note: *** refer to sig. level of 1%.

Observing that all statistics for all variables are significant at 1% level, the null hypothesis favoring the superiority of the linear model is not acceptable. Therefore, to estimate the relationships between the intended variables, non-linear approaches must be employed. Hence, as previously indicated, the NARDL model is an appropriate selection. In the subsequent step, the presence of a long-term relationship between the variables was tested using the aforementioned model, and the existence of this association was confirmed at a high level of significance (Table 4).

Following the confirmation of the long-term relationship between the variables, the long-term coefficients and the short-term relationships for positive and negative shocks in the independent variables were estimated.

Table 4. The result of cointegration test in the form of NARDL model.

Test result	Upper bound (95%) I(0)	Lower bound (95%) I(1)	F- statistic
Having a long-term relationship	4.33	2.69	8.23**

Note, ** refer to sig. level of 5%.

Table 5. Long-term and short-term coefficients in the form of a NARDL (Dependent variable agricultural energy consumption).

Variable	Long-term		Short-term	
	Coefficient	Probability	Coefficient	Probability
AVA^+	0.13	0.03	0.06	0.04
AVA^-	-0.09	0.06	-0.08	0.07
AEX^+	0.08	0.05	0.02	0.09
AEX^-	-0.02	0.08	-0.01	0.12
TO^+	0.16	0.03	0.03	0.05
TO^-	-0.11	0.06	-0.04	0.05
ECT(-1)	-	-	-0.48	0.04

Note: Variables are in the form of natural logarithms.

Table 6. Long-term and short-term coefficients in the form of a NARDL (Dependent variable agricultural energy productivity).

Variable	Long-term		Short-term	
	Coefficient	Probability	Coefficient	Probability
AVA^+	0.09	0.03	0.04	0.02
AVA^-	-0.09	0.06	-0.08	0.03
AEX^+	0.05	0.05	0.02	0.06
AEX^-	-0.02	0.08	-0.01	0.08
TO^+	-0.08	0.03	0.04	0.04
TO^-	0.05	0.06	0.07	0.05
ECT(-1)	-	-	-0.43	0.04

Note: Variables are in the form of natural logarithms.

In other words, it is necessary to estimate the effects of the long and short term on the dependent variable (energy consumption and agricultural productivity) concerning positive and negative impulses in the independent variables, and to ascertain if these two effects exhibit a significant difference (Asymmetry) or not (symmetry). Tables 5–8 list the required information.

Based on the results listed in Tables 5, 6, positive shocks in agricultural value added and trade openness had a significantly positive effect on energy consumption and agricultural productivity in the long term, and the positive shock of added value and trade openness has caused an increase in energy consumption and a decrease in productivity, respectively (In line with Islam et al. 2013; Sadeghpoor et al. 2018; Moradi et al. 2021; Wang et al. 2023).

Conversely, similar impacts from negative shocks were estimated inversely and insignificantly. Furthermore, these effects, as per Tables 7, 8, were also statistically significant, confirming the asymmetry in the effects of agricultural value added and trade openness on energy consumption and agricultural energy productivity, both in the short and long term. A similar inference is drawn regarding the short-term effects of agricultural value added and trade openness. In the case of agricultural exports, only positive shocks were observed to have an impact on energy consumption and agricultural productivity in the long term. The outcomes suggest that higher trade openness and stronger international relations contribute to increased exports and added value, subsequently leading to enhanced energy consumption and reduced productivity (In line with Vahidi 2004; Welsch and Ochsen 2005; Cole

Table 7. The results of asymmetry test in the effects of variables (Dependent variable agricultural energy consumption).

Short-term	Long-term	
(Probability)	(Probability)	Variable
8.14 (0.04)	8.27 (0.03)	AVA
7.47 (0.04)	6.84 (0.04)	AEX
9.15 (0.02)	8.22 (0.02)	TO

Table 8. The results of asymmetry test in the effects of variables (Dependent variable agricultural energy productivity).

Short-term	Long-term	
(Probability)	(Probability)	Variable
8.01 (0.04)	9.07 (0.02)	AVA
2.47 (0.07)	1.36 (0.08)	AEX
9.31 (0.02)	8.48 (0.02)	TO

2006; Armen et al. 2010; Sadorsky 2010, 2011; Halicioghlu 2011). The error correction coefficient for energy consumption and agricultural productivity variables was estimated as (-0.48) and (-0.43), respectively, and was found to be significant. This signifies that the effects of shocks will diminish within fewer than two periods.

Conclusions

This study delved into the nonlinear relationship between policy fluctuations and energy indices in Iran's agricultural sector. Recent years have seen considerable inclination among economists towards utilizing nonlinear models to explicate variable relationships. This preference is based on the differential responses of economic variables to the increase or decrease in each other, forming the basis for investigating the impact of policy oscillations on energy indices within Iran's agricultural sector through the application of the NARDL model during the period of 1967 to 2019. Also, despite political fluctuations due to sanctions in Iran and the effect of this issue on agriculture, a study in the form of non-linear models that takes asymmetry into account has not been done before.

The study utilized energy consumption and agricultural productivity as dependent variables, while independent variables included agricultural value added, agricultural exports, and trade openness within the agricultural sector. The findings revealed the significant influence of all independent variables on energy indices under scrutiny. In other words, the impact of positive and negative shocks on the drivers of the target variables (agricultural consumption and productivity) varied significantly in the long term. Notably, it was observed that the absolute magnitude of increasing shocks was more potent than decreasing shocks. Consequently, one could assert that positive shocks, particularly in agricultural value added, exports, and trade openness, exert a more intensified effect on the target variables (agricultural consumption and productivity). Moreover, it is suggested that to counteract the adverse effects of negative shocks on energy consumption and agricultural productivity, adopting “buffer” policies could be beneficial. Stability in economic (commercial) policies, as far as possible, should be considered. Establishing trade agreements can further mitigate the impact of political instability-induced shocks.

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