Forecast of Energy Consumption in Agricultural Sector of Iran Using Neural Network

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Abstract

Energy, as a major factor of production, plays an important role in economic activities. Shortages of energy resources and environmental aftermaths of unrestrained consumption of fossilized resources compel us to seek and implement most efficient ways and means to consume energy and hence the situation demands particular attention to be devoted to optimized energy consumption and its efficient use in energy related studies and policies throughout the world. In order to make forecasts on energy consumption in agricultural sector in Iran, we have applied neural network concept, we have calculated significant factors affecting energy consumption between 1974 and 2008 and then, Augmented Dicky-Fuller we have assessed durability or "stability" of variables. In addition, with the application of (Johansson's) test and Vector Error Correction Model (VECM), we have estimated long-term and short-term relationships of energy consumption in agricultural sector. Conclusions of this study indicate that intensity of energy consumption variable in agricultural sector and Gross Domestic Product (GDP) are of great importance and have a decisive and considerable impact on energy consumption in agricultural sector of Iran.

Keywords: Energy, Agriculture, Neural Network, Forecast

1. Introduction

Iran as a developing country with enormous energy resources, extensive oil reserves and large mineral deposits, is a model example of growth based on almost over-exploitation of natural resources (BaratiMalayeri, HooriJaffari, 2008) Prudent and balanced planning for production and consumption of energy is therefore of utmost importance and must be carried out with extreme care. Relative abundance of energy resources in Iran is the prime reason for higher per capita consumption of energy (amount of energy consumed to produce identical goods or services) compared with other countries with similar economic structures and less energy resources. (Energy Balance sheets, 2002). Energy is one of the principal factors of economic production. Irretrievability of resources and environmental problems caused by excessive consumption of these resources (in particular fossilized ones) demand urgent action to be taken for efficient use of energy and these serious circumstances and factors have put energy related issues at the centre of most research projects and policies regarding energy consumption (Haydari and Sadeghi, 2004). Diverse economic assessments of energy needs by policy makers as well as economists have concentrated on two aspects of the problem. First, the irretrievable depletion of fossilized resources that supply the greatest portion of world demand for energy and second, environmental pollutions that result from consumption of these resources. Generation of new and clean energy requires very large investments, the time for any return from such investments is too long and therefore most industrial states prefer to use scarce, still relatively cheap, depletable resources of third world countries. Further efforts to harness and generate new and clean energies depend on clear scientific analysis of potentially and actually accessible and financially remunerable projects and results. In such circumstances, importance of forecast on
consumption of energy is agricultural sector as well as other sectors become apparent. Forecasts on consumption, based upon new and operative scientific models, would help us to find ways and means to deal with this predicament and to make recommendations on adoption of policies, which promote and safeguard investments (Haydari, 2004). Cheap energy costs and factors like absence of modern technology in industrial plants, house building, agricultural production and transportation in Iran, are responsible for much higher per capita energy consumption than practically all developing or developed countries. This phenomenon is not only detrimental to environment and sustained economic development but imposes heavy costs on national economy. Rational utilization of energy resources and balanced planning for reaching optimized energy consumption, particularly in the light of extremely high subsidization expenses, seem very urgent. The first step in this direction was inclusion of article number 121 in the "Third Cultural and Socio-economic Development Plan" Law of the Islamic Republic of Iran, by which Ministry of Oil was commissioned to set up specialized committees to draw up standards and quotas for energy consumption in various sectors of economy. Subsequent to the Law's ratification, a new organization by the name of "Optimization of Energy Consumption Organization" was set up jointly by Oil Ministry and Ministry of power in order to oversee the implementation of the content of article 121 of that Law (Barati, Malayeri and H. Jaffari, 2008). The greatest portion of energy sources in Iran i.e. 98.5 percent of it comes from fossil fuel and unfortunately, the largest subsidy is allocated to them. The specific purpose of this paper is forecasting energy consumption in the agricultural sector of the country.

2. Literature Review

Masih (1997), employing Vector Error Correction Models (VECM), studied Granger's causality relationship between energy consumption, prices and real income in Korea and Taiwan. Price was included in the Model because it noticeably affected income and energy consumption in both countries. Conclusions of that study indicated that the rate of price fluctuation affects energy consumption that, in turn, affects the rate of economic growth. Cheng & Lai (1997), using Granger's causality test, arrived at a one-sided relationship between Gross National Product and energy consumption in 1955-1993 period for Taiwan. Oh & Lee (2004), using annual data from 1970 to 1999, examined causality relationship between energy consumption and economic growth in Korea. They also used a Vector Error Correlation Model with four variables i.e. Gross Domestic Product, energy consumption, employment and capital, to study relationship between energy consumption and economic growth. They showed that an increase in energy consumption entails substitution of capital for labour. The result of long-term and short-term causality test, also, indicated there exists a two-sided causality relationship between energy consumption and Gross Domestic Product in the long-term. In short-term, however, the relation is one-sided, from energy consumption to GDP. Glasure and Lee (1997) using annual data from 1961 to 1990, considered the relationship between energy consumption and real income in Korean economy. He expressed the view that absence of national income and energy consumption in previous studies could have been because effective variables on national income have been absent. His conclusion establishes a two-sided relationship between energy consumption and economic growth for that country. Employing Variance Analysis Method, he clearly showed that expanding financial and monetary policies have positive effects on national income and energy consumption, but it is the price of oil that exerts the greatest influence on national income and energy consumption. Zamani (2007) has studied causality relationship between NDP, value-added in agriculture and in industry and with the help of Vector Error Correction Model has shown there is a long-term one-sided relationship from NDP upon total energy consumption and a two-sided relationship between NDP and consumption of natural gaz. He also showed there is a long-term, two-sided relationship between value-added in agriculture and total energy consumed in this sector. Hondroyiannis et al. (2002) studied the relationship between energy consumption and economic growth in China and, likewise, using a Vector Error Correction Model studied the actual relationship between energy consumption and economic growth. Variables of the Model consisted of energy consumption, real GDP and energy prices. Their model, with the application of an efficiency criterion, shows that there is a long-term relationship between variables and that policy perspectives
emanating from this study indicates that if suitable policy structures for improvement of economic productivity are adopted we could witness stable energy consumption without adverse repercussions on economic growth.

Yang (2000) has also studied causality relationship between energy consumption and GNP, making use of data from 1945 to 1997. Results from Granger's causality test point to a two-sided relationship between total energy consumption and NDP. R. Mahadevan& J. AsafuAdjaye (2007) in an article entitled "Energy Consumption, Economic Growth and Prices: A Reassessment for Developing and Developed Countries", examined the relationship between energy consumption and real GDP of those countries. According to a combined error correction model and using data from 1971 to 2002, they have shown there is a two-sided long-term and short-term causality relationship between economic growth and energy consumption in oil-exporting countries. In oil-exporting developing countries, however, energy consumption positively affects economic growth only for a short time, In oil-importing countries whether developed or developing, in short-term as well as long-term, there is a two-sided causality relationship between energy consumption and economic growth. Amongst oil-importing countries, there is a one-sided causality relationship from energy consumption upon economic growth only in developed countries.

Xingjun, Zhao & Yanrui Wu (2007), using VECM technique analyzed demand for energy, particularly crude oil, in China and concluded that industrial output growth and development of transportation are dependent on imported energy irrespective of prices of crude oil on international market and has no alternative but to import it. G. W. Sun (2001) used a total analysis method. Basis of his research statistics was data on energy consumption and GDP over a stretch of time from 1960 to 1997. In this study Trend Effect, Rebound Effect and Materialization or Dematerialization Effect on consumption were estimated. These effects were a combination of structural, production-related and energy intensity effects and the obtained results showed that total energy demands in the 15 countries concerned in three distinct economic growth categories, low medium and high, increases from equivalent of 258 million tons of crude oil in 1997 to equivalent of 258, 427 and 980 million tons of crude oil in 2010.

Zibaii and Tarazkar (2004), based on Juselius and Johansen Co-Test within the framework of Vector Auto-Regressive Model, studied long-term and short-term relationships between value added and consumption of energy in agricultural sector of Iran from 1967 to 2000. They show that there is a long-term causal relationship between value added gained and energy consumption whether in the form of electricity or oil by-products. In short, term, also, value-added induces high electrical energy consumption while there is no short-term relationship between value added and consumption of oil by-products. Applying Vector Error Correction Model, Sohaili (2002) studied dynamic relationships between GDP, demand for energy prices in Iranian economy. To arrive at figures reflecting demand for oil by-products, electricity and gas, he estimated three distinct models, while GDP, quantity of energy and price of that energy carrier, were taken to account as endogenous variables. Maleki (1998) showed that, in short-term as well as in long-term there is a one-sided causality relationship from energy consumption onto GDP. Furthermore he also showed there is a weak relationship between economic growth (domestic production) and energy consumption only in long-term. In other words, any short-term change in production pattern could not affect energy consumption; in long-term, however, it marginally leaves its mark. But in short-term as well as in long-term, energy consumption does affect production pattern and any increase in consumption could increase production through higher productivity, demand etc. Energy consumption could also affect prices of goods and services generally and an increase in energy consumption leads to lowering prices.

Nilsaz et al (2007) has used Artificial Neural Network (ANN) in credit scoring of installment sales loan applicants and has showed that the Artificial Neural Network Model is of high efficiency and accuracy due to its flexibility. Fallahi et al (2006), has studied about the application of Artificial Neural Networks in forecasting revenues from job taxes in the economy of Iran. Komayja and Sa’adatfar (2006) have had a survey to evaluate the economic bankruptcy of companies in stock market using artificial neural networks. There are different methods to make forecasts; in present study, we shall make use of Neural Network Method together with Vector Error Correction Model in order to make forecasts about energy consumption in agricultural sector of Iran.
3. METHODOLOGY

3.1 A-Neural Networks

Neural networks are computational models through which we could establish relationships between inputs and outputs, themselves interconnected via knots, in a physical system. Degree and extend of activity of every connection is regulated by historical information (learning process) and the model would, eventually lead us to discover laws governing relationships between inputs and outputs, although these laws may be complex and non-linear. (Delavar, 2005).

3.2 Computational Principles of Artificial Neural Networks

Neutral networks consist of artificial neurons. Neurons or knots are the smallest information processing units that constitute the functional basis of neural networks. Each neuron takes in inputs and having processed them, generates output signals. Thus, each and every neuron acts as a processing and distribution information centre and has its own input and output. Figure (1) shows the schematic structure of a single-input neuron where (p) and (a) represent input and output respectively. The degree that (p)s exert influence upon (a)s is shown by a weighing coefficient (w). Another input is one, a constant number, which is multiplied by the biased sentence (b) and then added to the product of (w.p). The sum of this addition is the net input (n) for transfer or activation function (f). Therefore, neuron's output equation is expressed by:

\[ a = f(wp + b) \]

where (w) and (b) are adjustable and the function is chosen by designing operator. (w) and (b) are adjusted according to chosen function (f) and learning algorithm. Learning, in fact, means parameters (w) and (b) are so changed that the relationship between input and output of neuron approaches or rather tally with predetermined desired goal. There are however three important points concerning the operation of neurons: information required for a neuron to generate some outputs is actually present within the neuron itself and at its input gate, and no other information from other parts of the neural network is necessary. The second point is that each neuron generates only limited quantity of output which becomes either input to other neuron or output of the network. The third point is that each neuron acts independently which means that the output of any neuron depends entirely on its input and nothing else (Tarazkar, 2005).

Comparing neural network with Regression Models one could state that inputs in neural networks are independent variables and outputs are dependant variables, various weighing coefficients are similar to Regression Model parameters and "biased sentence" is the intercept or the constant sentence in Regression Model. If we add lags of dependant variables to all inputs then we shall have a network similar to Linear Auto-Regressive (AR) Model. In order to fully benefit from capabilities of neural networks, one employs linear activation functions in parts of the network. In an ideal situation, activation function ought to be continuous, differentiable and uniform because it facilitates the process of finding suitable algorithm coefficients (Rowshan, 2004). Neuron connections are so arranged to create a single layer or multiple layer network. Multiple layer networks are formed from an input layer to which input patterns are fed, an output, layer which determines the network's output, and in between the input and output layers there are one or many layers called hidden layers that interrelate the input and output layers. With these hidden layers, the network could derive nonlinear relationships from given data to the network, as shown in fig (2) (Rowshan, 2004).
3.3 Various Models of Artificial Neural Network

Artificial neural networks, depending on the manner information is fed and processed, are divided to the following groups:
1. Feed forward neural networks
2. Recurrent networks
3. Radial-basis function network
4. Multilayer perception networks

Since we have used Feed-forward neural network in this study we present a brief description of such network.

Feed-forward neural network

In these networks, the neurons (or knots) are arranged in serial layers and they have one-sided relationship and whenever and input pattern is introduced to the network, the first layer calculates its output quantities and delivers them to the adjacent layer (Figure 3). The process repeats itself i.e. the adjacent layer takes in those quantities as inputs and delivers its output to the next layer (Delavar, 2005).
3.4B. Error Correction Model (ECM)

Whenever involved variables are co-integrational in order to determine the short-term behavior of these variables we make use of EC Method introduced, for the first time, by Engle and Granger(1987). We ought to mention that, in this model, occasionally two variables may be co-integrational i.e. there is a long-term equilibrating relationship between the two, whereas in short-term there appears almost no equilibrium. Error correction model attempts to correct this short-term absence of equilibrium. (Noferesti, 1999). Therefore, if total energy (million barrels of oil equivalent) consumed in all production sector of national economy is represented by E and energy consumed in i the sector (million barrels of oil equivalent) is represented by Ei (Hydari, 2004) then

\[ E = \sum_{i=1}^{n} E_i \]  

(1)

We could rewrite this equation as

\[ E = \sum_{i} \left( \frac{E_i}{Q_i} \right) \left( \frac{Q_i}{GDP} \right) GDP \]  

(2)

Where (Qi) is value added in i th sector (million rials), GDP is Gross Domestic Product (million rials) and Ii is energy intensity ith sector (million barrels of oil/million rials) . If (Si) were

\[ I_i = \frac{E_i}{Q_i},\; S_i = \frac{Q_i}{GDP} \]  

(3)

to represent this sector's share in GDP then we have:

\[ E = \sum_{i} I_i S_i GDP \]  

(4)

One other parameter, which affects energy consumption, is the price and therefore effective parameter in energy consumption would be P. GDP.S.I. Where S, as stated before, represents share of the agricultural sector in GDP, which in turn reflects structural changes in national economy and P (rial) is the price of energy in agriculture sector. Total energy consumed in agricultural sector of Iran consists of various by-products of oil and electricity. In order to calculate the price of energy consumed in the sector we simply multiply the quantity of oil by-products and electric power consumed in the agricultural sector by their respective prices. In this study, we have observed in the field that energy consumption in agricultural sector is a function of energy intensity, agriculture's share in national economy, price of energy and Gross Domestic Product. Hereafter we shall devote our efforts to forecast energy consumption in the agricultural sector of Iran, using neural network and VECM tec.
4. Discussion and Results

In order to make forecasts about energy consumption in the agricultural sector, Importance Coefficients of model's variables are defined. Importance Coefficient for every parameter that bears influence upon energy consumption in the sector is shown in Table (1). Results obtained via neural network with 212 layers indicate that the following parameters i.e. intensity of consumed energy, agriculture's share in national economy and GDP have the greatest impact on energy consumption in Iran while energy prices bear no effect in this sector.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Importance Coefficient</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy intensity consumption</td>
<td>0.387</td>
</tr>
<tr>
<td>Agricultural sector share</td>
<td>0.354</td>
</tr>
<tr>
<td>Gross Domestic Product</td>
<td>0.131</td>
</tr>
<tr>
<td>Energy price</td>
<td>0.096</td>
</tr>
<tr>
<td>R2=0.9756</td>
<td></td>
</tr>
</tbody>
</table>

Table (1) Results obtained on variables affecting energy consumption in agricultural sector through application of neural network

Source: research founding

It is noteworthy that Importance Coefficient above 0.2 implies that the given variable certainly has an effect on the dependent variable. Thus according to table (1) it is clear that the variables of energy intensity and the share of agriculture in economy and GDP have a great impact on energy consumption, but the energy price hasn’t had a significant impact on energy consumption in agricultural sector for the considered period due to subsidies paid by the government.

Since variables under consideration are self-explanatory, hereafter, we shall apply Vector Error Correction Model to forecast energy consumption in agricultural sector.

Application of usual econometric methods to estimate pattern's coefficients, through application of time-serial data is based on the assumption that pattern's variables are stable. Before estimating the pattern, however, stability of variables was assessed and in order to do this, we used Augmented Unit Root Dicky-Fuller Test whose results are presented in Table (2).

<table>
<thead>
<tr>
<th>variable</th>
<th>Model</th>
<th>Stationary degree</th>
<th>Logs</th>
<th>Augmented Dickey-fuller statistic</th>
</tr>
</thead>
<tbody>
<tr>
<td>dE</td>
<td>Intercept</td>
<td>I(1)</td>
<td>0</td>
<td>-6.0447</td>
</tr>
<tr>
<td>dI</td>
<td>Intercept</td>
<td>I(1)</td>
<td>0</td>
<td>-5.3881</td>
</tr>
<tr>
<td>dS</td>
<td>Intercept</td>
<td>I(1)</td>
<td>0</td>
<td>-5.2185</td>
</tr>
<tr>
<td>dGDP</td>
<td>Intercept</td>
<td>I(1)</td>
<td>0</td>
<td>-3.1381</td>
</tr>
<tr>
<td>dP</td>
<td>Intercept</td>
<td>I(1)</td>
<td>0</td>
<td>-3.1350</td>
</tr>
</tbody>
</table>

Table (2). Results of Unit Root-Fuller Test

Note that critical Dicky-Fuller statistic at 1% level is equal to 3.6616, at 5% is equal to -2.9604 and at 10% level is -2.6191.
According to Unit Root Test, calculated and presented here, all above variables are stationary of the first degree (integration Ii) and therefore for Error Correction Model we have to determine the number of optimal lags.

Optimal lags Test

Johansson’s cointegration method has been used to estimate the long-run correlation between the variables in the survey. Analysis of the cointegration, based on Johansson’s approach, requires to determine the optimal lag length. The results of optimal lags test of the model variables (factors affecting energy consumption in Iran agriculture) according to the criteria of Akaike, Schwarz Bayesian, Hannan-Quinn and the LR test show an optimal lag equal to one.

Table (3). Results of Optimal lag Test.

<table>
<thead>
<tr>
<th>Lag</th>
<th>LogL</th>
<th>LR</th>
<th>FPE</th>
<th>AIC</th>
<th>SC</th>
<th>HQ</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>-584.4437</td>
<td>NA</td>
<td>2.26e+10</td>
<td>38.02863</td>
<td>38.25991</td>
<td>38.10402</td>
</tr>
<tr>
<td>1</td>
<td>-410.6098</td>
<td>280.3772*</td>
<td>1562472.*</td>
<td>28.42644*</td>
<td>29.81417*</td>
<td>28.87880*</td>
</tr>
<tr>
<td>2</td>
<td>-387.8662</td>
<td>29.34653</td>
<td>2071803.</td>
<td>28.57202</td>
<td>31.11619</td>
<td>29.40135</td>
</tr>
</tbody>
</table>

Source: research founding

Therefore having determined stability degree and optimal lag we shall make use of VEC Model for forecasting.

\[ E_i = \text{Energy consumed in agricultural sector (millions barrel of crude oil)} \]

\[ I_i = \text{Intensity of energy consumption (cost in Rial for production and distribution of each barrel)} \]

\[ \text{GDP} = \text{Gross Domestic Product (in billion Rials)} \]

\[ P = \text{Energy price in agricultural sector (Rials per litre)} \]

5. Estimated Results Derived from using VEC Model

Long-term and short-term coefficients, as the outcome of estimates derived from using VEC Model are:

\[
E(-1) = -0.97\left[ -24.21183J(-1) - 142.8702S(-1) - 0.0001.GDP(-1) + 0.0003. P(-1) + 35.729 \right]
\]

\[
(-13.6220) \quad (-17.1381) \quad (-13.1534) \quad (1.251)
\]

\[
-0.752.J(E(-1)) + 10.741.D(J(-1)) + 41.949.D(S(-1)) + 0.0001.D(GDP(-1)) + 0.0004.D(P(-1)) + 0.226
\]

\[
(-2.3417) \quad (1.139) \quad (0.739) \quad (2.764) \quad (1.370) \quad (0.584)
\]

\[
(5)
\]

Energy intensity, which reflects the amount of energy consumed per unit of production and is expressed in Rials per barrel of crude oil, has a substantial and decisive influence on energy consumption in agricultural sector. Gross domestic product at constant prices in 1997, has increased from 114,776 billion Rials in 1974 to 399334 billion Rials in 2006 (Central Bank of Iran, 2008). Future index of intensity of energy is a dependent function of productivity and optimization policies regarding energy consumption in relevant governmental departments. One of these policies which has preoccupied architects of the first socio-economic development plan up to the present and most likely in future is discontinuous and sustained increase of energy prices, auditing of energy, energy labeling, promotion policies and development of markets for efficient implements and machinery. If these policies continue to prevail in future, one could expect that intensity of energy in various economic sectors would correspondingly decrease. With passage of time, consumption of oil by-products would, most probably, fall but upward trend of intensity of electric power consumption would experience slowing down.
Agriculture's share in national economy(s) exerts a substantial and decisive influence on energy consumption, it somewhat bring to light the status of economic structure of the country and finally shows the extent that the sector's share affects energy consumption by the sector. GDP, too, has a substantial and decisive influence on energy consumption in agricultural sector, where energy is an essential input. Examination of energy figures in agricultural sector shows that, alongside increases in production and value added, consumption of all kinds of energy, including oil by-products and electric power, has increased during many past years.

Energy, as an indispensable factor of production, directly affects production and hence any increase in, say, agricultural production entails an increase in its consumption. But price of energy in agriculture has such a minimal negative effect on energy consumption that it is statistically negligible, which, in turn shows that energy consumption in agricultural sector is not a function of price variable. Energy prices in agricultural sector of Iran, however, are heavily controlled and subsidized by the government. In other words, energy prices, particularly prices of oil by-products, in agricultural sector are extremely low and have no noticeable bearing on consumption of energy in the sector; the coefficients that we have arrived at through present study, employing neural network technique, confirm this state of affairs.

Figure one also confirms the prediction accuracy of ANN.

6. Conclusion
Implementation of governmental protectionist policies for farming and farmers, diminishing role of middlemen, natural factors and modernization of agriculture in recent years have led to a surge in productivity. This phenomenon, in turn, has brought about a significant decrease in energy consumption and, as a follow up, a decrease in intensity of energy, so that intensity of energy has experienced a dramatic down-fall from 0.909988 (cost in Rial for production and distribution of each barrel) in 1991 to 0.566348 in 2006. Protectionist policies have, indeed, increased gross agricultural production but have simultaneously caused a sharp increase in energy consumption, mainly because of out of date technologies and traditional practices prevailing in this sector and also because of inordinately low price of energy, which is not conducive to energy saving mechanisms and behavior.

In order to achieve better economic growth and development, to control general prices of commodities, to maintain employment at an acceptable level or in sum, to realize social justice, heavy subsidies are paid on essential items, in general, and on energy, in whatever form, in particular. Food security is of prime importance, consequently energy prices for agricultural sector are under strict surveillance of the government, and therefore
prices have no effect on level of energy consumption in the sector. Since intensity of energy reflects the amount of final energy consumed per unit of production or value added, expressed, as we have already pointed out, in Rials, its impact actually measures variations in consumption as a result of any change in intensity of energy itself. Negative contribution of that impact between two years is indicative of decrease in consumption because of decrease in energy intensity and energy saving. Energy intensity is heavily dependent on methods of utilization of resources and energy-consuming machinery. Therefore, in any research work on economy of energy consumption and the role of saving, energy intensity is a key factor.

7. Suggestions

Increase in productivity in agricultural sector has brought about a marked decrease in energy consumption. Therefore, application of up to date technologies, modernization and use of hybrid seeds would lead to noticeable decrease in energy intensity in the sector. Digging of water from deep wells consumes a great deal of diesel oil and as diesel motor's efficiency is much lower that electro-motors one of efficacious means to save energy is to replace diesel motors with electro-motors.
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