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Forecasting Energy Demand in Jordan Using Artificial Neural Networks

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ABSTRACT

The purpose of this study is to forecast energy use in one of the MENA countries, Jordan using annual data over the period 1976-2008. The methodology used in this study follows the artificial neural networks analyses. We use four independent variables, namely, gross domestic product, population, exports, and imports to forecast energy use. The empirical results reveal that the projected energy use in Jordan will reach 8349, 9269, and 10189 Kt. of oil equivalent in years 2015, 2020, and 2025, respectively. Thus, a better and more realistic energy forecast is necessary for the policy makers when making decisions for the next decade. Therefore, the policy makers need to take this increase in energy use into consideration as it may pose a threat to economic development in the country should energy needs will not be met.

Keywords: Energy use forecasting; Neural Networks; Jordan
JEL Code: N75, O13, Q47

Introduction

Literature review shows that the artificial neural networks (ANN) models have been used in different fields such as psychology (Levine, 2006; Quek and Moskowitz, 2007), medicine (Gueli et al, 2005; Lisboa and Taktak, 2006), mathematics (Hernandez and Salinas, 2004), engineering (Pierre et al, 2001; Dharia and Adeli, 2003), finance (Wong and Selvi, 1998; Kumar and Walia, 2006; Angelini et al, 2008), and economics. As the literature shows, the applications of the ANN models in economics include sectors such as water resources (Hamed et al, 2004; Singh et al, 2009; Turan and Yurdusev, 2009; Firat et al, 2010), tourism (Palmer et al, 2006) and energy sector (Islam et al, 1995; Nizami and Al-Garni, 1995; Nasr et al, 2003; Murat and Ceylan, 2006; Sozen and Arcaklioglu, 2007; Azadeh et al, 2007 and 2008; Fadare, 2009; Geem and Roper, 2009; Sozen, 2009; Ekonomou, 2010; Geem, 2011; Kanka et al, 2011; Limanond et al, 2011).

Jordan has scarcity in domestic energy resources and it mainly relies on its imports to meet its energy demand. In terms of the world largest importers of oil and natural gas, Jordan ranks at the 43rd and 36th, respectively (EIA, 2008). In 2008, Jordan total imports of oil are about 95 thousand barrels per day. Jordan total imports of refined petroleum products increased from 17.674 thousands barrel per day in 2006 to 23.750 thousand barrels per day in 2007 (EIA, 2008). Jordan has about 90 thousand barrels per day of refining capacity in 2009. The energy demand forecasting for a country is important for both policymakers and investors.

The main goal of this study is to forecast the demand for energy in Jordan over the period 2010-2025 using socioeconomic indicators. The study will use the artificial neural networks (ANN) model to achieve this goal. The variables used in this study are energy consumption (dependent variable), and four independent variables such as: gross domestic product (GDP), population, exports, and imports. The model will use historical data on those variables over the period 1976 to 2008. All the data will be extracted from the World Bank, World Development Indicators database.

The rest of the paper is organized as follows. Section 2 presents data set and input variables used in the study. Section 3 presents modeling and discusses the empirical results while section 4 concludes the study.

Data set and input variables

The data used in this study were collected from the World Development Indicators, World Bank. It includes the following inputs: Gross Domestic Product (GDP), Population (P), Exports of Goods and Services (EX), and Imports of Goods and Services (IM). These inputs were also used in the literature for predicting energy use (see for example: Ceylan and Ozturk, 2004; Toksari, 2007; and Geem and Roper 2009). The output is energy consumption (E). Annual data for all these variables (inputs and output) are available for the period 1976-2008. It is worth mentioning that there are other inputs that can affect energy consumption besides those selected inputs mentioned above. However, due to the data availability, this study limited itself to those inputs.

Over the period of 1976 to 2008, energy use in Jordan has increased from 951 ktoe to 7061 ktoe while Gross Domestic product has increased from 1.61 billion to 9.3 billion Jordanian Dinars. Also, over the same period (1976-2008), the population, exports, and imports have increased by 208.43%, 460.07%, and 333.19%, respectively.

Modeling and Results

The neural networks model is used to predict the energy consumption in Jordan using the following inputs: Gross Domestic Product (GDP), Population (P), Exports (EX), and Imports (IM). The model used in predicting energy consumption is given in the following equation:

$$E = f\,(GDP, P, EX, IM)$$

Where GDP, P, EX, and IM are as defined above.

Following the literature, the neural network model used in this study to predict the yearly energy consumption is the Multilayer Perceptron (MLP) feed forward model with backpropagation training technique with three layers: inputs layer, hidden layer, and output layer as shown in figure 1 (Ekonomou2010, Geem and Roper 2009).

The transformation functions used are the tangent hyperbolic for the hidden layer and the sigmoid function for the output layer. Literature shows that the backpropagation is the most commonly used technique in training the neural network. The process of determining the neural networks models depends on the structure of the network, the transfer function and the learning algorithm. Thus, using the backpropagation technique, the MLP process is determined by a) using different combinations of number of hidden layers and nodes in a hidden layer, b) using different transfer functions, and c) learning algorithms that lead to select the best model architecture which leads to minimize the sum squared error (SSE) (Ekonomou2010).

The data set is divided into two subsets: training (70%) and testing (30%). The training process goal is to minimize the sum squared error (SSE). Regarding the activation function, we use the sigmoid function at the output layer and tangent hyperbolic function at the hidden layer. The neural networks models are determined based on their architecture, thus we use different architecture in the MLP by varying the number of hidden layers and the number of nodes in each hidden layer.

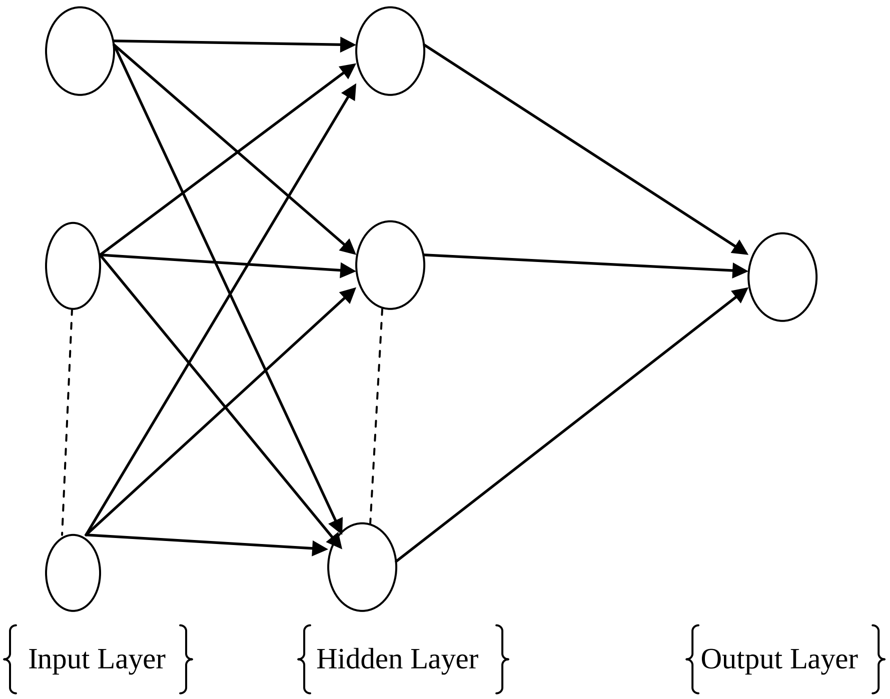

Figure 1: Neural Network Architecture

Table 1 shows different architectures of the neural network models used with their corresponding SSE values.

Table 1

Errors from Various Neural Network (NN) Models

Errors	Architecture of the NN Model			
	5-5-1	5-10-1	5-5-5-1	5-5-10-1
SSE	0.01	0.015	0.004	0.037

After producing the model for predicting the energy consumption (target variable) in Jordan based on the values of the predictor variables listed above by using the MLP procedure, we use that model to predict energy consumption up to the year 2025. To do so, we will use two scenarios: a) the average growth rates in the independent variables, and b) the government projected growth rates for the independent variables. Table 2 shows the forecasted results over the period 2010-2025. The energy use in Jordan is expected to increase to 8349, 9269, and 10189 Kt. of oil equivalent in years 2015, 2020, and 2025, respectively.

Table 2

Energy Use Forecast for Jordan
2010-2025

Year	Energy use (kt of oil equivalent)
2010	7429
2011	7613
2012	7797
2013	7981
2014	8165
2015	8349
2016	8533
2017	8717
2018	8901
2019	9085
2020	9269
2021	9453
2022	9637
2023	9821
2024	10005
2025	10189

Conclusion

This study uses the artificial neural networks model to forecast the energy use in Jordan up to year 2025. The model uses a data set collected over the period 1976 to 2008 of the following variables: GDP, population, exports, and imports as inputs, and energy use as an output. The neural network model with the best performance was used to predict the energy use for the target period. As the results show, the expected energy use will reach 8349, 9269, and 10189 Kt. of oil equivalent in years 2015, 2020, and 2025, respectively.

Thus, a better and more realistic energy forecast is necessary for the policy makers when making decisions for the next decade. Therefore, the policy makers need to take this increase in energy use into consideration as it may pose a threat to economic development in the country should energy needs will not be met. However, it should be noted that if these forecasts are overestimating (underestimating) the true energy needs of the economy in the future, it may end up in increasing the risk of government budgeting more than (less than) what is needed for energy related projects. Thus, it is recommended that other energy forecasting models be used to verify the results and also energy projections should be repeated as the circumstances change.

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