Using Artificial Neural Networks to Recognize the Determinants of Energy Consumption in Saudi Arabia

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ABSTRACT

This study aims to investigate the variables affecting Saudi Arabia's energy consumption. To do this, the study used an innovative technique called an artificial neural network (ANN) between 2010 and 2020. The findings of this study indicate that global energy prices, followed by industrialization and trade openness, are the most significant factors influencing Saudi Arabia's energy consumption. Saudi Arabia's energy consumption is not influenced by other variables, such as population growth, inflation, urbanization, economic growth, which have been addressed in other works.

Keywords: Saudi Arabia, Energy Consumption, Artificial Neural Network
JEL Classifications: O13, O20. Q43

1. INTRODUCTION

The primary source of energy in the world is Saudi Arabia, which produces petrochemicals, natural gas, and oil. The Ministry of Energy, Industry, and Mineral Resources is in charge of it, while Saudi Aramco is in charge of exploration, refining, and related activities. For the purpose of creating effective energy policies and managing these elements and associated environmental problems, it is necessary to identify and investigate the factors that determine a nation's energy consumption.

The Kingdom's Vision 2030 aimed to develop a national program aimed at improving and raising the efficiency of energy consumption in three main sectors, which account for more than 90% of domestic energy consumption: buildings, industry, and land transport. Among the most prominent efforts to reduce energy consumption are the coverage of more than 180 production lines within the regulatory framework for energy efficiency for the industrial sector, and the development of 26 standards and regulations for energy efficiency with the aim of improving energy

efficiency in the building sector, and in the road transport sector, several initiatives have been developed to improve the energy efficiency of light vehicles These efforts were accompanied by the implementation of a number of main possibilities, such as the application of strict control procedures for energy efficiency products, and the development and qualification of national capabilities in this field through specialized and public training courses. To implement audit and rehabilitation projects for buildings.

The main factors influencing energy consumption have been the subject of several studies (Mostafa and Selmey, 2022; Mostafa, 2021; Hassan, 2018). The application of these studies varied, with some of them interested in researching these variables in industrialised or developed nations—whether in Asia or Europe—and others in researching them in developing countries.

Indeed, some studies (Mostafa and Selmey, 2022; Mostafa, 2021; Fernandez and Reddy 2021; Ridzuan et al., 2020; Morelli and Mele, 2020) have demonstrated that the most significant

determinants of energy consumption are "FDI, Investment, population density, urbanisation, renewable energies from water sources, climate change and population growth industrialization, economic One of these studies, which applied to India, China, Malaysia, Indonesia, the Philippines, and Thailand, revealed that industrialization, exchange rate, trade openness, and financial development are the main factors influencing energy consumption in China. In the same way, the study demonstrated that, while industrialization is the primary influence on energy use in India and Thailand, we discover that energy use in Indonesia and trade openness in Malaysia are the primary factors in each of those countries. The study (Rafidadi, 2014) also sought to identify the factors that influence energy in Germany. It came to the conclusion that the most significant factors influencing its energy consumption are capital utilisation, financial development, and trade openness.

Finally, it can be claimed that the use of a relatively new tool in this study's investigation of the factors influencing energy consumption in Saudi Arabia is its most significant aspect. Artificial neural networks are this tool (ANN). This study is therefore one of the very few to attempt to apply neural networks to a variety of economic issues.

Thus, the purpose of this study was to determine the major factors that influence energy consumption in Saudi Arabia. This study has been divided into the following four components with the following purposes: Introduction and review of the literature are in Section 2, Methodology and Data Section 3, Results and conclusions are in Section III.

2. LITERATURE REVIEW

Numerous policies have recently been implemented to optimize energy consumption efficiency. The factors that influence energy consumption in developed (e.g France, the United States, Canada) and developing (e.g., Nigeria, South Africa, Kenya, Pakistan) countries have been the subject of several empirical research. The factors influencing energy consumption in the economy of Saudi Arabia are remain unclear.

For the purpose of examining the subsequent research questions, this literature can be split into six types of studies.

Throughout discussions of these study questions are provided below. The first study question looks at the relationship between economic growth and energy consumption. Because it has such a significant impact on the economic growth among many countries, this study subject has attracted the attention of economists and policymakers. Numerous studies have also shown that one of the major factors that influences energy consumption is economic growth. The relationship between economic growth and energy consumption in New Zealand from 1960 to 2004 was investigated by (Warr and Ayres, 2010). Its results supported the notion that energy consumption is a derived demand, demonstrating that economic growth drives energy consumption and that economic performance determines the increase in demand also (Gozgor et al., 2018) found that an increase in non-renewable and renewable energy consumption is associated with a boosted economic growth rate.

The relationship between industrialisation and energy consumption was the subject of the second research question. This relationship is looked into by (Mostafa and Selmey, 2022; Gungor and Simon, 2017; Fernandes and Reddy, 2021). The results indicated that industrialization affects energy consumption positively, especially over the long term.

On the other hand, (Mostafa and Selmey, 2022; Li and Lin, 2015) examined how the industrialization of 73 nations between 1971 and 2010, divided into four categories based on income levels, affects energy consumption. According to the study, both middle-/low-income and high-income groups' energy consumption reduces as a result of industrialization. The middle-/high-income group's energy consumption is unaffected by it.

The third research question is to investigate how population growth and energy consumption are related. (Mashhoodi et al., 2020; Wang et al., 2021) who research the factors that influence energy consumption look at this relationship. The results reveal that the main cause of increases in industrial energy consumption is population size. The macroeconomic factors that influence energy consumption are also explained by (Samuel et al., 2013; Azam et al., 2016). According to the results, one of the major factors that influenced energy consumption was population growth.

The fourth question aims to clarify the relationship between urbanisation and energy consumption. According to (Wang et al., 2021), the income effect of urban residents was the main factor contributing to the rise in household sector energy consumption. As a result, (Wang et al., 2019) examined the impact of urbanisation on per-capita energy consumption in 186 nations classified into three categories between 1980 and 2015. (high income, upper, and lower-middle-income groups). In high- and lower-middle-income countries, Granger causality research looked at a bidirectional causality between urbanisation and energy consumption, but there was none in the upper-middle-income group. The study corroborated the evidence that urbanisation has a significant impact on per capita energy consumption.

The relationship between oil prices and energy use is the subject of the sixth research question. Numerous research has sought to investigate this relationship, including (Osigwe and Arawomo, 2015; Abid, 2020). Long-term bi-directional causality between the price of oil and energy consumption was shown by the results.

However, (Mostafa and Selmey, 2022; Haque, 2021) examines the link between energy consumption and energy prices, concentrating on price shocks for crude oil in the Gulf Cooperation Council's energy exporting countries from 1985 to 2014. As a result, the findings demonstrate that fluctuations in the price of oil have a detrimental effect on energy consumption.

The impact of trade openness on energy consumption is the subject of the last research question. We'll use a few studies to explain this relationship. For instance, (Fernandes and Reddy, 2021) investigated the factors impacting energy consumption in a number of Asian countries between 1980 and 2018, including China,

India, Indonesia, Malaysia, the Philippines, and Thailand. It was discovered that China and Malaysia's energy use increases with trade liberalisation. Additionally, from 1973 to 2014, (Lu, 2020) investigated the connection between trade openness and energy consumption in 13 Asian nations. The results then supported a single-direction causal relationship between trade openness and energy consumption.

Similarly, (Rafindadi and Ozturk 2017) looked into whether trade openness affected South Africa's energy consumption between 1970 and 2011. The findings demonstrated that increased trade openness promotes South Africa's energy demand and raises energy consumption. Additionally, from 1972 to 2011, (Arif et al., 2017) looked at the relationship between trade openness and energy consumption in the oil-importing Asian nations of China, India, Bangladesh, and Pakistan. This study concludes that trade liberalisation reduces energy use. International trade also drives up economic performance and energy demand.

3. DATA, METHODOLOGY AND RESULTS

Using a model of an artificial neural network, we look into to the factors that influence energy consumption in Saudi Arabia.

The ANN model employed in the study is shown in Equation No. (4), which has the following form (Mostafa and Selmy, 2022; Ahmed and Mater, 2021):

$$Y_t = F\left[H_1 X_{t-1}, H_2 X_{t-2} H_N X_{T-N}\right] + U \qquad (1)$$

Y_t: output layer and represents the dependent variable, expressing economic growth.
X_1, X_N: input layer and represents explanatory variables or independent variables.
F, H: function of neural network
H: represents Hidden Layer Activation Function
F: represents the output of Hidden Activation Function
U: Error Term.

The variables and data sources are listed in Table 1. Energy consumption, the dependent variable, is shortened throughout the duration of the study (EC). When determining energy consumption, seven variables are regarded as independent variables.

The neural network design and the factors influencing energy Consumption in Saudi Arabia were determined using the SPSS version (22) application. The neural network design depicted in Figure 1 has three layers. The first layer, which has seven variables, is the input layer, which represents the independent variables. The second layer is the hidden layer, which is made up of one neuron. The third layer is the output layer, which is represented by the dependent variable energy consumption (Ec).

The number of periods in the network training phase is (6) at a rate of (66.6%) of the total data, as shown in Tables 2 and 3. The sum of squares of error in the training phase is (1.214) and the relative error is (0.015), whereas the sum of squares of error in the testing phase is (0.064) and the relative error is (0.022),
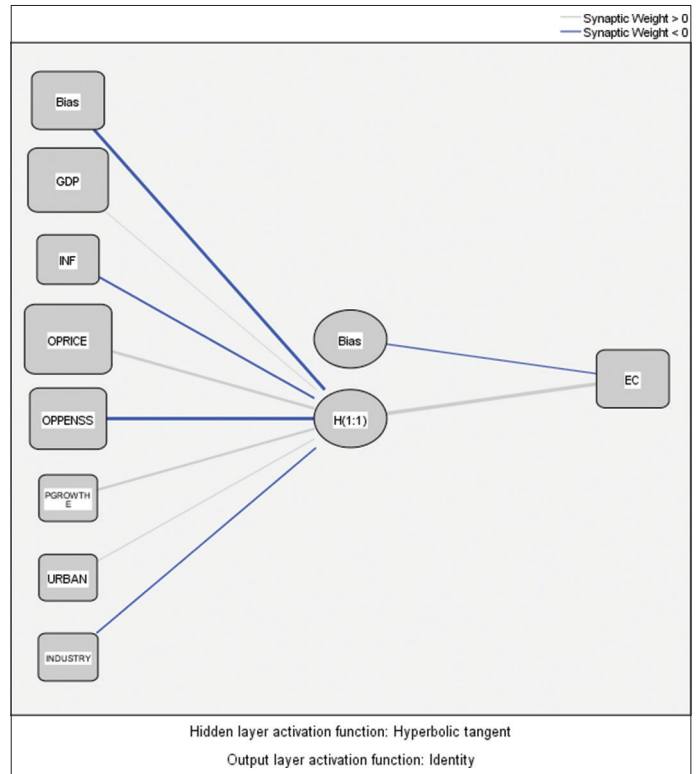
Figure 1: Neural network architecture

Hidden layer activation function: Hyperbolic tangent
Output layer activation function: Identity

Table 1: Independent variable

Variable	Symbol	Source
World oil price	Oprice	The global economy database
Trade openness	Oppenss	The global economy database
Population growth rate	PGROWTHE	The global economy database
Urbanization	Urban	UNCTAD database
Industry growth rate	Industry	The global economy database
Inflation	INF	The global economy database
Economic growth	GDP	The global economy database

Source: The author

applying multilayer perceptron (MLP). There is no doubt that a low relative error number shows the model's accuracy and quality.

Table 4 shows the relative importance of the independent variables in the neural network model. The international price of oil, industrialization, and economic openness are the three major factors that influence energy consumption in Saudi Arabia, according to Table 4. This has been accomplished as a result of these determinants' rising relative importance in comparison to other determinants. With a standard value of 100%, the relative importance of the price of oil around the world was around 0.395. With a standard value of 70.4%, industrialization's relative importance was approximately 0.251. The same was true for economic openness, which had a standard value of 67.3% and a relative importance of roughly 0.213. As for the remaining determinants, which include population growth, economic growth, urbanisation, and inflation rate, Table 4 demonstrates that their influence on energy consumption is very modest. Together, these variables' relative importance was approximately 0.141. There is no doubt that this demonstrates

that the world oil price, industrialization, and openness to the outside world are the key determinants of energy consumption in Saudi Arabia.

It is clear from Table 5 that Saudi Arabia's energy consumption is negatively impacted by both inflation and the price of oil. The remaining determinants have a positive impact on Saudi Arabia's energy consumption. These factors include population growth, urbanisation, industry growth rate, economic openness, and economic growth.

Table 2: Case processing summary

Summary	n	Percent
Sample		
Trainig	6	66.6
Testing	3	33.4
Valid	9	100.0
Excluded	1	
Total	10	

Source: Spss v. 22 output

Table 3: Model summary

Training	
Sum of squares error	1.214
Relative error	0.015
Stopping rule used	1 consecutive step (s) with no decrease in errora
Training time	00:00.0
Testing	
Sum of squares error	0.064
Relative error	0.022

Dependent Variable: EC, a. Error computations are based on the testing sample,
Source: Spss v. 22 output

Table 4: Independent variable importance

Variables	Importance	Normalized importance (%)
GDP	0.096	0.9
INF	0.041	15.3
OPRICE	0.395	100.0
OPPENSS	0.213	67.3
PGROWTHE	0.003	0.7
Urban	0.001	0.3
Industry	0.251	70.4

Source: Spss v. 22 output

Table 5: Parameter estimates

Predictor	Predicted	
	Hidden layer 1	**Output layer**
	H (1:1)	**EC**
Input layer		
(Bias)	−0.453-	
GDP	0.021	
INF	−0.182	
OPRICE	−0.214	
OPPENSS	0.135	
PGROWTHE	0.347	
Urban	0.121	
Industry	0.167	
Hidden layer 1		
(Bias)		−0.211-
H (1:1)		0.654

Source: Spss v. 22 output

In light of this, the link between the factors influencing energy consumption as an independent variable and the dependent variable, energy consumption, as a dependent variable, is expressed in the following equation.

$$EC = 0.021GDP - 0.182INF - 0.214OPRICE + 0.135OPPENSS$$
$$+0.347PGROWTH + 0.121URBAN + 0.167INDUSTRY$$

4. CONCLUSION

The primary source of energy in the world is Saudi Arabia, which produces petrochemicals, natural gas, and oil. The Ministry of Energy, Industry, and Mineral Resources is in charge of it, while Saudi Aramco is in charge of exploration, refining, and related activities.

For the purpose of creating effective energy policies and managing these elements and associated environmental problems, it is necessary to identify and investigate the factors that determine a nation's energy consumption.

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Despite the fact that there have been numerous studies on this subject, this one stands out because, on the one hand, it is one of the first studies to use artificial neural networks, which are distinguished by organizing independent variables according to the strength of their impact on this dependent variable, and, on the other hand, it is applied to Saudi Arabia when and this topic is particularly significant to Saudi Arabia when establishing its public policies, particularly in light of the COVID crisis, fluctuations in global energy prices and Vision of the Kingdom of Saudi Arabia 2030.

The main variables impacting Saudi Arabia's energy consumption are trade openness, industrialization, and global energy prices, according to the study's results. The study found that other variables that affect energy consumption, such as foreign direct investment (FDI), population growth, economic growth, inflation, and so on, have a negligible effect on Saudi Arabia's energy consumption.

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