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Article

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Determinants of Energy Consumption in Egypt "New Approach"

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ABSTRACT

In Egypt, policymakers are particularly concerned about energy consumption. So, the goal of this study is to look into the factors that influence Egyptian energy consumption. The study applied a new approach known artificial neural network from 2000 to 2020 to achieve this goal. according to the results of this study, global energy prices are the most important determinants of Egyptian energy consumption, followed by economic growth and trade openness. Other factors such as population growth, inflation, urbanization and industrialization, which have been highlighted in other papers, are not determinants of Egyptian energy consumption. this research recommends that need to follow policies that rationalize energy consumption and improve the efficiency of its use.

Keywords: Energy Consumption, Artificial Neural Network, Determinants, EGYPT
JEL Classifications: O13, O20. Q43

1. INTRODUCTION

One of the most basic requirements for economic growth is the availability of permanent energy sources. In recent years, energy consumption has increased rapidly in all countries around the world (Mostafa, 2021). Furthermore, because energy consumption is one of the most basic inputs for many economic activity, one of the most essential things for economic policymakers is to rationalize energy consumption improve the efficiency of its use.

Identifying and studying the determinants that affect a country's energy consumption is required in order to develop suitable energy policies and control such factors and related environmental issues.

Several studies (Obadi and Korček, 2015; Shah et al., 2015; Kahouli, 2017; Hassan, 2018) have focused on researching the main determinants of energy consumption. These studies varied in the field of application, as some of them were interested in studying these determinants in industrialized countries or developed countries, whether in Asia or Europe, and some were interested in studying these determinants in developing countries.

Anyway, Some studies (Fernandes and Reddy, 2021; Ridzuan et al., 2020; Morelli and Mele, 2020; Dumrul, 2019; Sarkodie et al., 2018; Gamoori et al., 2017) have shown that the most important determinants of energy consumption are "FDI, Investment, population density, urbanization, renewable energies from water sources, climate change and population growth industrialization, economic openness, and economic growth". One of these studies is like a study (Fernandes and Reddy, 2021) by applying to India, China, Malaysia, Indonesia, the Philippines and Thailand showed that the most important determinants of energy consumption in China are industrialization, exchange rate, trade openness and financial development. In the same context, the study showed that while industrialization is the main driver of energy consumption in India and Thailand, we find that energy consumption in Indonesia and trade openness in Malaysia is the main determinant of energy consumption in each of them. Moreover, the study (Rafidadi, 2014) was interested in searching for the determinants of energy in Germany. It concluded that capital use, financial development and trade openness are the most important determinants of its energy consumption.

Finally, it can be said that the most important feature of this study is that it uses a relatively recent tool in the search for the determinants of energy consumption in Egypt. This tool is artificial neural networks (ANNs). Therefore, this study is one of the very few studies that seek to apply neural networks in various economic phenomena.

Hence, this study aimed to identify the main determinants of energy consumption in Egypt. For this purpose, this study has been divided into four sections as follows: Section (I): Introduction and literature review. Section (II): Data and Methodology. Section (III): Results and Conclusion.

2. LITERATURE REVIEW

Recently, many policies have been implemented to enhance the efficiency of energy consumption. Numerous empirical studies examine the determinants of energy consumption across developed (France, United States, Canada) and developing (e.g., Nigeria, South Africa, Kenya, Pakistan) countries. However, little is known about the determinants of energy consumption in the Egyptian economy.

This literature can be divided into six groups of studies to explore the following research questions. First, how economic growth affects energy consumption? (Saidi and Hammami, 2015; Gozgor et al., 2018). Second, what is the link between industrialization and energy consumption? (Fernandes and Reddy, 2021; Gungor and Simon, 2017; Li and Lin, 2015). Third, does population growth influence energy consumption? (Wang et al., 2021; Mashhoodi et al., 2020; Sarkodie and Adom 2018). fourth, what is the relationship between urban population and energy consumption? (Wang et al., 2021; Wang et al., 2019; Bakirtas and Akpolat, 2018). fifth, how does the oil price affect energy consumption? (Haque, 2021; Abid, 2020; Zouand Chau, 2020). sixth, to what extent does openness trade impacts energy consumption? (Fernandes and Reddy, 2021; Lu, 2020; Arif et al., 2017).

The following will discuss these research questions in detail. The first research question examines the relationship between economic growth and energy consumption. This research question had great attention for economists and policymakers because of its essential impact on the economic performance of various countries. In addition, numerous studies have revealed that economic growth is one of the major energy consumption determinants. (Bartleet and Gounder, 2010; Warr and Ayres, 2010) examined the link between economic growth and energy consumption in New Zealand from 1960 to 2004. Its results showed that economic growth causes energy consumption, and the economic performance determines the increase of energy demand, consistent with the rule that energy demand is a derived demand. According to (Gozgor et al., 2018) the impact of renewable and non-renewable energy consumption on the economic growth in the 29 countries of the Organization for Economic Co-operation and Development from 1990 to 2013. The paper has found that an increase in non-renewable and renewable energy consumption is associated with a boosted economic growth rate.

Moreover, (Islam et al., 2013; Saidi and Hammami, 2015; Sineviciene et al., 2017; Topolewski, 2021) investigate the same relationship. It was found that economic growth has a positive effect on energy consumption in the short and long run. Where increasing the production process has increased energy consumption. Also, this relationship takes a one-way direction, directed from economic growth to energy consumption and not the other way around.

The second research question has examined the relationship between industrialization and energy consumption. This relationship is investigated by (Gungor and Simon, 2017; Fernandes and Reddy, 2021). The results revealed that industrialization has a positive impact on energy consumption especially in the long run.

On the other hand, (Li and Lin, 2015) explored how energy consumption is affected by the industrialization of 73 countries over 1971–2010, classified into four groups based on income levels. The study found that industrialization decreases energy consumption in the middle-/low-income and high-income groups. However, it does not have any effect on energy consumption in the middle-/high-income group.

The third research question aims to study the relationship between population growth and energy consumption. This relation is examined by (Mashhoodi et al., 2020; Wang et al., 2021), who study determinants of energy consumption. The results reveal that Population size is the main driver for increments in industrial energy consumption. Likewise, (Samuel et al., 2013; Azam et al., 2016) explain the macroeconomic determinants of energy consumption. The results found that population growth was one of the main determinants of energy consumption.

The fourth question tries to explain the relationship between urbanization and energy consumption. (Wang et al., 2021) found that the income effect of urban residents was the most significant driver behind the increase in household sector energy consumption. As such, (Wang et al., 2019) studied the effect of urbanization on energy consumption per capita during 1980–2015 in 186 countries divided into three groups (high income, upper, and lower-middle-income groups). Granger causality analysis investigated a bidirectional causality between urbanization and energy consumption in high and lower-middle-income countries but no causality in the upper-middle-income group. The study supported the evidence that urbanization is an important factor affecting energy consumption per capita. In this context, (Bakirtasand Akpolat, 2018) found abidirectional causality between urbanization and energy consumption in New emerging-market countries. On the other hand, (Zhao and Wang, 2015) found that a unidirectional causality running from urbanization to energy consumption.

The fifth research question examines the association between oil price and energy consumption. Many studies have attempted to examine this relationship, such as (Osigwe and Arawomo, 2015; Abid, 2020).The Findings demonstrated a bi-directional causality between oil price and energy consumption in the long run.

However, (Haque, 2021) investigates the relationship between energy consumption and energy prices, focusing on shocks in crude oil prices in energy-exporting countries of the Gulf Cooperation Council from 1985 through 2014. Consequently, the results show that oil price shocks have a negative impact on energy consumption.

The final research question targets the impact of trade openness on energy consumption. We are going to explain this relation by some studies. For instance, (Fernandes and Reddy, 2021) identified the factors that affect energy consumption in some Asian countries such as China, India, Indonesia, Malaysia, The Philippines, and Thailand during 1980–2018. It was found that trade openness leads to energy consumption in China and Malaysia. Also, (Lu, 2020) examined the relationship between trade openness and energy consumption of 13 countries in Asia from 1973 to 2014. Then, the finding confirmed a unidirectional causality running from trade openness to energy consumption. Likewise, (Rafindadi and Ilhan, 2017) investigated whether trade openness contributed to energy consumption in South Africa during 1970–2011. The results showed that trade openness stimulates energy demand in South Africa and increases energy consumption. Moreover, (Arif *et al*., 2017) examined the impact of trade openness and energy consumption in oil-importing Asian countries, namely China, India, Bangladesh, and Pakistan, from 1972 to 2011. This paper finds that trade openness has a positive impact on energy consumption. Additionally, international trade increases energy demand and economic performance.

3. DATA AND METHODOLOGY

We investigate the determinants of energy consumption in Egypt using an ANN model.

An ANN is a model that constructs a new structural system to simulate the biological nervous system in the human body for information processing. This connects organizes several of the processing elements, which are neurons, so that they can work together to solve the phenomenon being studied (Mohamed Ahmed and Mater, 2021).

A neural network is made up of a group of neurons that are connected to each other by weighted connections represented by arrows and is denoted by the symbol W_{ij}. The j receives the inner signals of $X = [X_1,\ldots,X_n]$ from the units (cells/nodes) attached to them from the previous layer. Each signal is associated with a specific weight $W_j = [W_{1j},\ldots,W_{nj}]$ (Mohamed Ahmed and Mater, 2021).

Layers are used to organize the neurons. The input layer of the network is where each node corresponds to an independent variable. Each node in the input layer is connected to all nodes in the hidden layer, and the network may have more than one hidden layer. The layers come to end with an Output Layer, which is a node (or multiple nodes) that represents the dependent variable (or dependent variables). (Mohamed Ahmed and Mater, 2021).

The W_{ij} weight is calculated by the sum of the product of multiplying the node weights from which it emits in the node values (independent variables) (Mohamed Ahmed and Mater, 2021).

Weights in a neural network express flexible coefficients in reaction to signals going through the network, based on an appropriate learning algorithm and threshold (also known as bias), which is equivalent to the intersection limit in a regression model (Mohamed Ahmed and Mater, 2021).

The combination function examines the input signals, their weights, and the interval value for each cell. The combination function generates a single value called potential for each cell (or net input). The activation function is responsible for converting the potential into an output signal (Mohamed Ahmed and Mater, 2021).

The potential P_j is the sum of the deviations of the previous cell values X_i weighted by the weights coming out of them W_{ij} from the interval value θ_j, because the combination function is usually linear. This is expressed in Equation No. (1) (Mohamed Ahmed and Mater, 2021):

$$p_j = \sum_{i=1}^{n} \left(x_i w_{ij} - , _j \right) \quad (1)$$

The signal out of cell j (y_j) can be obtained by applying the activation function to the potential p_j to give the following equation (Mohamed Ahmed and Mater, 2021):

$$y_j = f\left(\mathbf{p_j}\right) = f\left(\sum_{i=0}^{n} x_i w_{ij}\right) \quad (2)$$

The neural network can be activated in a variety of ways. The linear approach, piecewise method, Sigmoidal method, and Softmax method are among the most well-known. The sigmoidal approach, which is an S-shaped curve, is the most widely used method in empirical studies. This function provides a positive result exclusively in the interval [0, 1], and it has two common functions, the hyperbolic function and the logistic function. The following equation (Mohamed Ahmed and Mater, 2021) defines it:

$$f\left(p_j\right) = \frac{1}{1+e^{-p_j}} \quad (3)$$

Neural networks are used because, unlike other methods, they don't require any preconditions or assumptions, and they're separated from the competition by their high flexibility and capacity to produce acceptable solutions. It was used in this study because it arranges the independent variables according to the importance of their effect on the dependent variable, which is exactly what the researcher wants to know in order to understand the factors that influence energy consumption.

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

$$Y_t = F\left(H_1 X_{t-1}, H_2 X_{t-2},\ldots, H_N X_{T-N}\right) + U \quad (4)$$

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.

Table 1 contains the variables and data sources. The dependent variable is Energy consumption, which is abbreviated throughout the rest of the study (EC). Seven variables are considered independent variables when it comes to determining energy consumption.

A program SPSS ver. (22) was used to determine the neural network architecture and know the determinants of energy consumption in EGYPT. There are three layers in the neural network architecture shown in Figure 1. The input layer, which represents the independent variables, is the first layer which consist of seven variables. The hidden layer, which consists of one neuron, is the second layer. The output layer, which is represented by the dependent variable, energy consumption (Ec), is the third layer.

The number of periods in the network training phase is (15) at a rate of (78.9%) of the total data, as shown in Tables 2 and 3. The sum of squares of error in the training phase is (1.134) and the relative error is (0.162), whereas the sum of squares of error in the testing phase is (0.098) and the relative error is (0.062), applying multilayer perceptron. There is no doubt that a low relative error number shows the model's accuracy and quality.

The proportional importance of the independent variables in the neural network model is shown in Table 4 and Figure 2. Table 4 shows that there are three main determinants of energy consumption in Egypt, and these determinants are the international price of oil, economic growth and economic openness. This has been achieved as a result of the increasing relative importance of these determinants compared to other determinants. The relative importance of the world oil price amounted to about 0.385, with a standard value of 100%. The relative importance of economic growth reached about 0.292, with a standard value of 75.9%. The same case applied to economic openness, as its relative importance was about 0.248, with a standard value of 64.3%. As for the rest of the other determinants represented in population growth, urbanization, industrial output growth rate and inflation rate, Table 4 shows that their impact is very limited in energy consumption. The relative importance of these variables together amounted to about 0.075. There is no doubt that this shows that the main driver of energy consumption in Egypt is, respectively, the world price of oil, then economic growth, and then openness to the outside world.

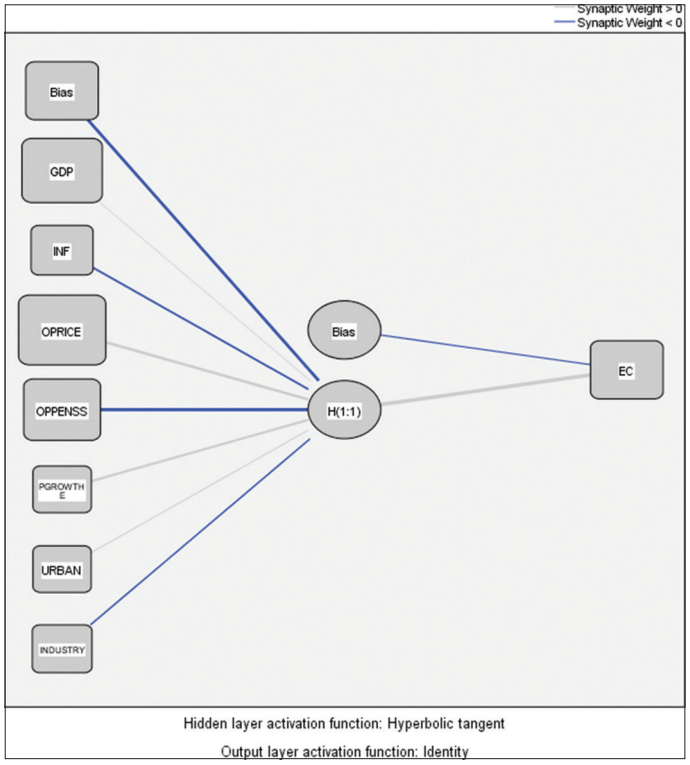
From Table 5, it can be concluded that there is a negative impact of both inflation and the world oil price on energy consumption in Egypt. As for the rest of the determinants, they have a positive impact on energy consumption in Egypt. These determinants are economic growth, urbanization, industry growth rate, population growth and economic openness.

Table 1: Independent variables

Variable	Symbol	Source
Economic growth	GDP	The Global economy database
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

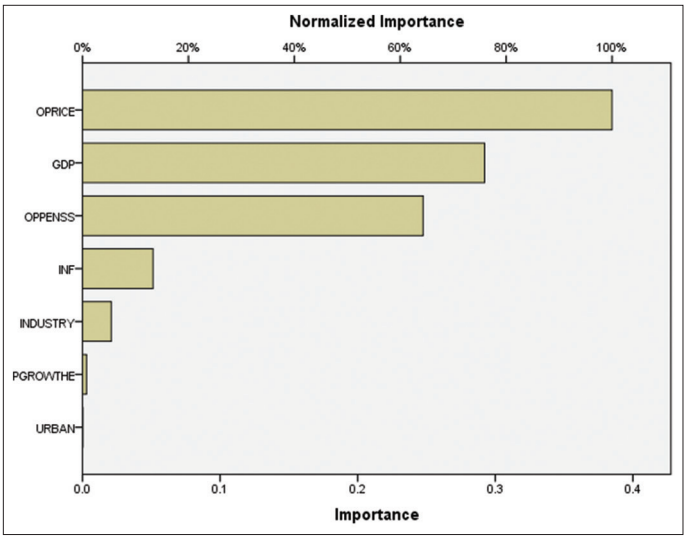
Source: The author

Figure 1: Neural network architecture



Source: Spss v.22 output

Figure 2: Independent variable importance



Source: Spss v.22 output

Table 2: Case processing summary

	N	Percent
Sample		
Trainig	15	78.9
Testing	4	21.1
Valid	19	100.0
Excluded	1	
Total	20	

Source: Spss v. 22 output

Table 3: Model summary

Training	
Sum of Squares Error	1.341
Relative Error	0.162
Stopping Rule Used	1 consecutive step (s) with no decrease in error[a]
Training Time	00:00:00.013
Testing	
Sum of Squares Error	0.098
Relative Error	0.062

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

Table 4: Independent variable importance for low-income developing countries

	Importance	Normalized Importance
GDP	0.292	75.9%
INF	0.051	13.3%
OPRICE	0.385	100.0%
OPPENSS	0.248	64.3%
PGROWTHE	0.003	0.8%
URBAN	0.000	0.1%
INDUSTRY	0.021	5.4%

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	0.007	
INF	−0.191-	
OPRICE	−0.433-	
OPPENSS	0.540	
PGROWTHE	0.357	
URBAN	0.044	
INDUSTRY	0.176	
Hidden Layer 1		
(Bias)		−0.117-
H (1:1)		0.819

Source: Spss v. 22 output

Accordingly, the following equation expresses the nature and direction of the relationship, between energy consumption as a dependent variable, and the determinants affecting it as independent variables.

EC = 0.007 GDP – 0.191 INF – 0.433 OPRICE + 0.540 OPPENSS + 0357 PGROWTH + 0.044 URBAN + 0.176 INDUSTRY

4. CONCLUSION

Energy consumption play an important role in the economic policies set by developing countries in particular because of their special importance in achieving social justice.

Although there are many studies that have focused on this topic, this study differs from them in that it is one of the first studies that used ANN, which are characterized by arranging independent variables according to the degree of their impact on this dependent variable on the one hand, and on the other hand it is applied to Egypt and this topic has particular importance to Egypt when setting its public policies, especially in light of the COVID-19 crisis, fluctuations in global energy prices, and the increase in external public debt.

The study concluded that the most important determinants of energy consumption in Egypt are global energy prices, economic growth and trade openness. There is no doubt that this is due to the economic growth in Egypt that is based on export industries that are mainly energy consuming industries, as there is a committee in Egypt that changes energy prices every 3 months based on the change in global energy prices, which indicates that what the study found has an relevance on the ground. Other determinants of energy consumption studied in other papers, such as FDI, population growth, industrialization, inflation, and so on, have a limited impact on energy consumption in Egypt, according to the study.

Based on the above, the study recommends the necessity of taking into account the determinants that most affect energy consumption in Egypt when developing any policy that would rationalize energy consumption and improve the efficiency of its use.

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