# 8. FORECASTING AND THE CAUSAL RELATIONSHIP OF SECTORIAL ENERGY CONSUMPTIONS AND GDP OF PAKISTAN BY USING AR, ARIMA, AND TODA-YAMAMOTO WALD MODELS

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## Abstract

*The objective of this research was to forecast the sectorial energy consumption of Pakistan for five fiscal years, i.e., from FY18 to FY23 using two different time series techniques and explore the causal relationship between total energy consumption and its sectorial components, and Gross Domestic Product (GDP). The study further analyzed the efficiency of two different time series models, such as the Autoregressive model (AR with seasonal dummies) and Autoregressive Integrated Moving Average model (ARIMA/ARMA). In any economy, forecasting energy consumption and its relationship with GDP is paramount to ensure the economic development and fiscal policies. This study used components of total energy consumption (TEC) such as domestic energy consumption (DEC), commercial energy consumption (CEC), industrial energy consumption (IEC), agricultural energy consumption (AEC), transport energy consumption (TrEC) and other government energy consumption (OGEC). The data is taken from FY1977 to FY2017 (41 annual observations) and focused on forecasting for FY18 to FY23. For the forecasting of total energy*

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*consumption independently and taking the sum of all sectorial components. The results of this study revealed that among these models, the ARIMA model gives better-forecasted values for Pakistan's total energy consumption. The findings of the Granger causality test shows that there is no causal relationship between CEC, OGEC, and GDP variables and there is a one-way causal relationship between IEC & GDP, the direction is from IEC to GDP. The Toda & Yamamoto Wald model's findings demonstrated similar results, and there is one-way causation from IEC to GDP.*

**Keywords:** Energy consumption forecasting; GDP forecasting; ARIMA/ARMA model; AR model with seasonal dummies; Granger causality model; Toda & Yamamoto Wald model

**JEL Classification**: C53, O40, Q4

## 1. Introduction

The economy of every country depends on energy production and consumption. Thus, the energy is termed as the lifeblood of economic growth and the sustainable economic growth, human development, and standard of living of a country depending on the adequate availability of relevant energy [1]. The history of world economic development serves as a witness for the nexus of energy availability and economic growth of a country. The industrial revolution is the outcome of using steam and other factors; the high standard of living in developed countries was achieved due to the consumption of oil and gas. The economic growth of middle east countries was directly related to the extraction of oil. The backbone of emerging economies is the adequate supply of energy in different sectors of the economy [2,3].

Pakistan is one of the emerging economies with a population of around 200 million, the annual population growth rate of 2%. With this huge population and high population growth rate, Pakistan needs massive energy resources [4]. However, it has been struggling to meet its demand for energy in the form of Oil, Natural Gas, and Electricity. The electricity shortfall crossed the edge of 6000 MW in July 2018 [5]. The reserves of natural gas are depleting rapidly, and a gas shortfall of 8 (BCFD) by the year 2025-26 is expected [5]. According to the Monitoring report [6], the import bill of oil may touch $20 billion for the current FY19. With this worst scenario, it is challenging for a country to achieve sustainable economic development, cope with the evil of unemployment, reduce the absolute and multidimensional poverty, improve the score in HDI, cater the issues of transportation, and meet the requirements of domestic demand for energy [7]. On the commercial front, there are several impediments about the production of primary, secondary and tertiary goods due to the shortage of electricity. As a result, the trade deficit has been rising day by day, and it has reached $18.9 billion in FY18 [8].

To cope with the issues of the energy crisis, several long-term and short-term measures are required. One approach is to find out the current needs for energy in the economy and exploring the availability of energy resources to meet the current demand [9]. However, energy resources are volatile, and they are subject to depletion. Further, the future demand for energy is also subject to change due to population growth, economic growth, and business variations. One of the biggest challenges of Energy Economics is to estimate the future energy requirements concerning variations in demography, economic activities, and infrastructure for transport and communication [10]. Estimation on the energy consumption in different sectors of the economy is inevitable to cope with the challenges concerning the development of various sectors of the economy, which include domestic consumers, commercial energy consumers, industrial energy consumers, agricultural energy consumers, transport energy consumers, and other governments energy consumers [11]. This estimation helps the policymakers, regulatory bodies, and government agencies to do appropriate planning to encounter the future needs of energy consumption of the country.

To comprehend the energy consumption pattern in the country, we need to explore various sectorial components energy. There are six major components of total energy consumption (TEC) and its six sectorial components such as domestic energy consumption (DEC), commercial energy consumption (CEC), transport energy consumption (TREC), agricultural energy consumption (AEC), industrial energy consumption (IEC), and other governments' energy consumption (OGEC). Pakistan lacks in almost all types of energy components. Besides understanding the pattern of energy consumption and forecasting of the next five years, this is also pertinent to explain the influence of energy consumption on the GDP of Pakistan [7]. In developed economies, the consumption of energy has a direct impact on GDP growth. However, in Pakistan, around 50% of the population lives in rural areas where the availability of electricity and gas is not as per the demand due to poor infrastructure. So, the relationship and intensity of energy consumption on the GDP growth of a developing country like Pakistan need to be established with empirical shreds of evidence [12].

### *1.1. The objective and significance of the study*

The purpose of the undertaken study is to examine the six sectorial energy consumption components, and total energy consumption, and their individual and overall impact on the economic growth of Pakistan. Apart from the casual association, we aim to predict individual sectorial component of energy consumption, and total energy consumption for the next five years. We have used also explored the most efficient model of forecasting for energy consumption in Pakistan. The undertaken study not only provides the forecasting of individual sectorial components of total energy consumptions but also gives the total energy consumption forecasting without taking six components. Thus, we compare the individual result of energy consumption to a total of six sectorial components of energy consumption, moreover to compare both total energy consumption patterns with the economic growth of Pakistan. This study would help the government and regulatory bodies to do planning based on the forecasted demand of energy and look for the energy resources to meet the future requirements. Further, this will help chalk out an effective fiscal policy, energy policy, and other relevant policies. This will also help the energy sector look for new resources or expand the capacity of existing energy resources. It will also help investors plan their business by the future requirements of energy.

The remainder of this research study divided into four further fragments: 2) part two contains on previous literature, 3) section three comprises of material and methods, and 4) part four demonstrates the results and estimations of this study. However, 5) segment five deals with discussions and conclusions of the undertaken research.

## 2. Substantiation from previous literature

### *2.1. Nexus of energy consumption & economic growth*

The interconnection of economic growth (GDP), and energy consumption (EC) has been under review for a long time. If there is a relationship between them, the policymakers are required to focus on the degree of impact of either of them on each other. There are four schools of thought, and they advocate hypotheses such as the neutrality hypothesis that demonstrates no causal association amid total EC and EG. However, the conservative hypothesis supports a causal association from EC to EG. Whereas, the growth hypothesis indicates that GDP growth causes EC, and finally, as per the feedback hypothesis, there is two-ways causal association amid EC and EG [13,14].

### *2.1.1. The neutrality hypothesis*

A couple of studies were conducted on this hypothesis. Altinay and Karagol [15] conducted a study using Hsian's form of Granger causality, taking data from 1950 – 2000 in Turkey. They established no cogent causal association amid total energy consumption and economic development (GDP). Another study was conducted in Turkey for the last forty years and concluded the same result [16]. Significant research was carried out in which 17 African countries were taken, and data was used from 1960 – 2001, this research also concluded that no significant causal association amid economic growth and energy consumption [17]. Similarly, Yu and Jin [18] have employed Co-integration and test of Granger causality and found there was no relationship between the variables. Tzeremes [19] has conducted a critical study on the US economy; he took a period from 1991 – 2016, used the quantile causality technique to explore the association, and concluded an asymmetric causal association amid economic growth, and energy consumption. Acheampong [20] has conducted imperative research for 116 countries for the period from 1990 – 2004; he employed PVAR and System-GMM and concluded no causal association amid economic growth (EG), and energy consumption (EC). Mann and Saphton [21] have conducted research for four countries, such as Indonesia, the Philippines, Thailand, and India. They used data from 1971 – 1995 with cointegration and ECM techniques, and concluded no causation between EC and EG. Similarly, Fatai et al. [22] have researched for India, Australia, New Zealand, Philippines, Thailand, and Indonesia for the period 1960 – 1990; they employed ARDL and Toda-Yamamoto causality models and concluded that there is no causal relationship ascertained between EC and EG. According to Yu and Hwang [23], and Akarca and Long [24], there is no causal association between EG and EC for the US economy in which they used Sim's technique for the period 1950 – 1970 and 1947 – 1949 respectively. Similarly, Yu and Jin [18] have conducted research for the US for the period 1974 – 1990; they employed cointegration and Granger causality and concluded similar results. In the same vein, Cheng [25] has carried out the research for the period of 1947 – 1990 and found similar results in the case of the US economy. Halicioglu [26] used the Toda-Yamamoto causality model for the data set 1960 – 2005 and concluded no causality amid EC and EG in Turkey. According to Soytas and Sari [27], no causality existed amid EG and EC for Turkey, and they employed the Toda-Yamamoto causality model by using a data set of 1960 – 2000. Similarly, Payne [28] also used the Toda-Yamamoto causality model, considering the sample period 1949 – 2006 in the US and concluded similar results. Tugcu and Topcu [1] have conducted significant research for G7 countries to examine the causal association of EC and EG. They employed NARDL and asymmetric causality models for the period from 1980 to 2014, and they concluded an asymmetric long-term causal association amid EG and EC.

### *2.1.2. The Conservation hypothesis*

Another school of thought finds empirical shreds of evidence of causality from energy consumption (EC) to economic growth (EG). Belloumi [29] used VECM and Granger causality models, and he considered the data from 1974 – 2011, the outcome of this research demonstrated that the energy consumption has the causal association to the economic growth in a short-term in case of Tunisia. Yildirim et al. [30] used Hatemi–J causality and Tota & Yamamoto causality techniques and concluded that there is the compelling influence of energy consumption on the GDP for the period 1949 – 2010 in case of Germany. Andrei et al. [31] employed a four-panel root test and using 17 variables and endorsed this phenomenon. Esso and Keho [32] also found similar results. Lee and Chang [33] have taken a data set of 1954 – 2003 for Taiwan; they employed Johansen-Juselius, and Granger causality techniques, and concluded unidirectional causation from EC to EG. Similar study was replicated for the period 1955 – 2003, and employed cointegration, VECM, and Granger causality techniques, and concluded the similar results [34]. Similarly, Ang [35] has taken data from 1960 – 2000, and employed cointegration and VECM techniques; he also infers the same result of one-way causation from EC to GDP in France. Pao et al. [36] have employed NGBM-OP and MAPE techniques for the period 2009 – 2010 for China and concluded the uni-directionality from EC to GDP. Likewise, Stern [37] has taken data from 1947 – 1990 for the US economy; he employed multivariate VAR model, and concluded unidirectional causality from EC to EG. Similar study was replicated for the data set 1948 – 1994 for the US; he employed cointegration and Granger causality, and concluded the same results [38]. In Korea, Oh, and Lee [39] have considered the data from 1970 – 1999; they used ECM and Granger causality models and demonstrated the unidirectional causality from EC to EG. Bowden and Payne [40] have employed Granger, and Toda & Yamamoto causality methods for the period 1949 – 2006, and proven a unidirectional causality from EC to EG for the US. Pinzón [41] has conducted research to investigate the causal association between EC and EG in Ecuador, and he has taken the data set of 1970 – 2015, employed Granger causality, and VAR models. He concluded a one-way causal association from EC to EG. Gozgor et al. [42] have carried out research for data set of 29 OECD countries for the period 1990 – 2013, they employed Panel Quantile regression, and ARDL modeling, and concluded one-way causation from EC to EG. Appiah [14] has conducted research in Ghana and explored the causal association and EG; he used ARDL, Granger & Toda-Yamamoto causality techniques, and cointegration model. He considered the data set from 1960 to 2015, and concluded the unidirectional causality from EC to the EG. Kourtzidis et al. [2] have carried taken a data set from 1991 to 2016 in the case of the US and concluded similar results. Kahouli [43] has also conducted research for Mediterranean countries and concluded the same results.

### *2.1.3. The Growth hypothesis*

An ample amount of literature is also available to support this hypothesis. Kraft J. and Kraft A. [44] are the pioneers of this-this hypothesis. They employed Granger causality model to investigate the causal association between economic growth (EG), and energy consumption (EC); they used the data from 1947 to 1974 and endorsed this hypothesis, and concluded the causality from EG to EC. Karanfil [45], Lise and Van Montfort [46], Cheng [47], and Zhang and Cheng [48] were few of the prominent advocates of this hypothesis. Chen et al. [49] have carried out significant research on lower-income, and lower-middle-income economies for the data set 1998 – 2014, they employed ECM and Granger causality models. They concluded one-way causation from EG to EC. According to Abosedra and Baghestani [50], there is a unidirectional causal association from EG to EC in the US economy; they used the data for the period 1947 – 1987 by employing Granger causality, and cointegration methods. Similarly, in Taiwan, Cheng and Lai [51] concluded the similar results for the data set 1954 – 1993 by using Granger causality. Soytas et al. [52] have carried out the research in Turkey for 1960 – 1995 by exercising cointegration and Granger causality techniques and confirmed similar results. Cheng [53] has conducted significant research for Japan; they used the data set of 1952 – 1995 by using Hsiao's Granger causality model and concluded one-way causation from EG to EC. Zamani [54] has conducted research for Iran for the data set of 1967 – 2003 by using cointegration and VECM techniques and concluded the one-way causation from EG to EC. In a similar vein, Ang [55] has conducted imperative research in the case of Malaysia, he used the data from 1971 to 1999 by using VECM and cointegration techniques and concluded similar results. Zhang and Cheng [48] have conducted an essential study in the case of the Chinese economy. They used the data from 1960 – 2007 by using the Granger causality model, and they concluded the unidirectional causal association from EG to EC. Nyasha et al. [11] have conducted a critical study to explore a casual association amid economic growth and energy consumption in the case of Ethiopia, they employed multivariate Granger causality and ARDL models for the data set 1971 – 2013 and concluded one-way causality from EG to EC. Lee and Jung [13] have carried out significant research in South Korea, employing cointegration, VECM, and ARDL bound testing approaches to explore the causal association. They considered the data set from 1990 to 2012, and they concluded the one-way causation from EG to EC.

### *2.1.4. The Feedback hypothesis*

The bi-directional causal association was another essential element that is supported by the literature. Erol and Yu [56] were one the oldest researcher who endorsed this relationship employing the Granger causality model by taking data from 1952–1982 of 6 industrialized countries. They found two-ways causality amid economic growth and energy consumption. Masih A. and Masih R. [57], Asafu–Adjaye [58], Saytas and Sari [59], Nachane et al. [60], and Lee et al. [61] are some other researchers who endorsed this relationship. Xie et al. [62] carried out significant research for the US, China, Germany, Canada, France, South Korea, and Japan, they have used Panel threshold model for the period from 1997 – 2016. They have established the two-way causation from EC–GDP and GDP–EC in the case of R&D manufacturing. Warner et al. [63] have also conducted significant research for the period 1972 – 2014 by using the Wavelet technique in case of 74 countries, and they concluded the bidirectional causal association amid economic growth (EG), and energy consumption (EC). According to Soytas and Sari [64], there is two-way causation between EC and EG in Turkey; they employed VECM and Granger causality models for the period 1960 – 2000. Erdal et al. [65] have also confirmed similar results in Turkey's case; they used the data set from 1970 – 2006 by employing Granger causality and cointegration methods. In the same vein, Paul and Bhattacharya [66] have carried out an essential study for India. They used the 1950 – 1996 data set by employing Granger causality and cointegration methods, and they concluded two-ways causal association amid EC and EG. Ghali and El-Sakka [67] have used the data set of 1961 – 1997 for the Canadian economy; they used cointegration, VECM, and Granger causality techniques. They concluded the two-way causal directional between EC and EG. Similarly, Hondroyiannis et al. [68] have found similar results in Greece's case; they considered the data set of 1960 – 1996 using ECM model. Glasure [69] also confirmed the similar results in the case of South Korea for the data from 1961 – 1990 by using cointegration, ECM, and VD models. In the same vein, Hwang and Gum [70] concluded similar results in the case of Taiwan for the period 1961 – 1990 by using ECM and cointegration techniques. Ohlan [71] has carried out significant research for the Indian economy for the data set from 1971 – 2016; they employed cointegration and Granger causality techniques and concluded the two-way causal association between EC to EG. Bakirtas and Akpolat [3] have examined the causal association amid EC and EG, they employed Dumitrescu-Hulin panel Granger causality model for Colombia, Kenya, Malaysia, India, Indonesia, and Mexico for the data set from 1971 to 2014, and they concluded the bidirectional causality between the variables.

## 2.2. Literature on Pakistan

Pakistan is one of the middle-income economies with a high unemployment rate, low HDI, and a high score on MPI. The energy crises have been a significant issue for the last two decades for Pakistan. The trade deficit of the country is very high due to high imports and low scale of exports. The GDP of the country has always been uncertain due to many factors, and lack of availability of adequate energy is one of the elements. Several research pieces have been conducted to explore the causal association between economic growth and energy economics in the case of Pakistan. Jamil and Ahmad [72] used a 3-factor model by employing VECM Granger causality and cointegration models by using data from 1960 to 2008 for Pakistan. They concluded that GDP caused an increase in electricity consumption. The sectorial growth in agricultural, commercial, and manufacturing sectors caused a rise in energy consumption. Siddique [73] attempted to examine the association and used capital stock, petroleum products, and electricity consumption as independent variables and concluded that electricity consumption, petroleum energy, and capital stocks have a causal influence on GDP in the long run from 1971 – 2003. Imran and Siddique [74] investigated three SAAR Countries, including Pakistan using Granger Causality, found a positive causal influence of energy consumption on economic growth in the long-term. Some other local studies have also been carried out in recent times, such as Siddique [4] has carried out vital research to investigate the causality amid EC and EG. He employed cointegration and Granger techniques to explore the association for the period from 1980 – 2016 and concluded a bidirectional causality between the variables. Similarly, Chandio et al. [10] have employed ARDL modeling for the period from 1984 – 2016 and concluded similar results. Rehman and Deyuan [7] used ARDL bound testing, and cointegration techniques for the period from 1990 – 2016, and found the uni-directionality amid energy consumption to GDP of Pakistan.

## 2.3. Energy Forecasting

Another essential element in forecasting energy consumption so that the policymakers can devise the plan for meeting the people's future energy requirements and ensuring sustainable economic and social development. There are several time series data techniques used for forecasting such as Moving average and exponential smoothing (MA&ES), Case-based reasoning (CBR), Artificial neural network (ANN), Fuzzy time series, Autoregressive integrated moving average (ARIMA), Grey prediction model, and Support vector machines (SVM). However, literature support that ARIMA and AMRA are the best models for forecasting purpose [75]. Several researchers use ARIMA Model for forecasting purposes. For instance, Katara et al. [76], Mohamed et al. [77], Abledu [78], and Wang et al. [79] have used ARIMA with certain variations.

## 2.4. Research Gap

Although an ample amount of previous literature is available on the consumption of energy consumption and economic growth (EG) nexus for an international perspective, sufficient literature is not available in Pakistan. Further, a minimal amount of literature is available using time series data for 1977 – 2018. Lastly, all the sectorial constituents of total energy consumption (TEC), and its six sectorial components such as domestic energy consumption (DEC), commercial energy consumption (CEC), transport energy consumption (TREC), agricultural energy consumption (AEC), industrial energy consumption (IEC), and other governments' energy consumption (OGEC) have not been used in any of previous literature in the Pakistani context. The undertaken study not only provides the forecasting of individual sectorial components of total energy consumptions but also gives the overall energy consumption forecasting without taking six components. Thus, we compare the individual result of total energy consumption to a total of six sectorial energy consumption components and analyze both aggregate energy consumption patterns with the economic growth of Pakistan.

# 3. Materials and Methods

In this research, the annual time series of TEC and its six important sectorial components, i.e., DEC, CEC, AEC, TrEC, OGEC, and GDP, were collected from different Pakistan Energy Yearbook issues and Pakistan Economic Survey respectively. The time horizon for the undertaken research is considered the data set FY1977 – FY2017, with 41 observations. We used secondary time series data and forecasted total energy consumption (TEC), and its six sectorial components for six years i.e., from FY2018 to FY2023. Two univariate time series models are proposed for forecasting the series used in this research. The total energy consumption (TEC) and its six sectorial components are estimated by using the Autoregressive (AR) model, and Autoregressive integrated moving average (ARMA/ARIMA) model. For comparing both econometrics time series techniques, we employed root mean square error (RMSE), and mean absolute error (MAE) criterion, ARIMA, and AR models have minimum RMSE & MAE is considered being the best-forecast compare to other models.

# 4. Results

## *4.1. Augmented Dickey-Fuller test (ADF) and Philips-Perron test (P-P) Tests*

The null hypothesis of ADF and Philips-Perron (P-P) tests statistics have a unit root that refers to the data series is non-stationary. From Table 1, the result reveals that series TEC, AEC, DEC, and TREC are stationary at levels i.e., these series are I(0). In contrast, the remaining series CEC, IEC, OGEC, and GDP are stationary at 1$^{st}$ difference i.e.; these series are said to be I(1).

**Table 1**

**The outcome of ADF & P-P tests**

| | At Level | | | At Ist Difference | |
|---|---|---|---|---|---|
| Variables | Value | P-value | | Value | P-value |
| | | ADF Test Statistics | | | |
| AEC | -2.7999 | 0.0673 | | | |
| CEC | -1.0261 | 0.7344 | | -10.2859 | 0.0000 |
| DEC | -4.2697 | 0.0016 | | | |
| IEC | -1.8405 | 0.3562 | | -5.4566 | 0.0001 |
| OGEC | -1.3481 | 0.5977 | | -7.3028 | 0.0000 |
| TREC | -2.7092 | 0.0813 | | | |
| TEC | -3.9353 | 0.0042 | | | |
| GDP | -1.6801 | 0.4334 | | -4.6885 | 0.0005 |

| | At Level | | | At Ist Difference | |
|---|---|---|---|---|---|
| Variables | Value | P-value | | Value | P-value |
| PP Test Statistics | | | | | |
| AEC | -2.7999 | 0.0673 | | | |
| CEC | -1.1542 | 0.6846 | | -28.8293 | 0.0001 |
| DEC | -4.3820 | 0.0012 | | | |
| IEC | -1.8405 | 0.3562 | | -5.4519 | 0.0001 |
| OGEC | -1.0830 | 0.7132 | | -7.5368 | 0.0000 |
| TREC | -3.0690 | 0.0371 | | | |
| TEC | -3.9378 | 0.0041 | | | |
| GDP | -1.3178 | 0.6120 | | -4.7854 | 0.0004 |

*Note: MacKinnon, one-sided p-values at 1% level: -4.0370, at 5% level: -3.4480, at 10% level: --3.1491.*

### *4.2. Forecasting Energy consumption: AR model*

Table 2 exhibited the results of Autoregressive model for different orders that are estimated for total energy consumption (TEC) and its six sectorial components such as domestic energy consumption (DEC), commercial energy consumption (CEC), transport energy consumption (TREC), agricultural energy consumption (AEC), industrial energy consumption (IEC), and other governments energy consumption (OGEC), and forecasting is done for the period from FY2018 to FY2023. TEC # forecast also obtained by adding the forecasted values of its sectorial components. Forecast for FY2018 of TEC # is 52.8 billion from the sum of all forecasted values of its sectorial components, whereas 52.9 billion is obtained from AR model of TEC*; there is no significant difference between these two forecasted values. However, there is a significant difference in forecasted values of TEC # for FY2023 from these two techniques (i.e., by using AR model to TEC # and sum of all forecasted values of its sectorial components), 70.6 billion from applying AR model to TEC # whereas 57.4 billion for the sum of forecasted values of all components of TEC*. However, the forecasted GDP for FY2018 is $36.53 billion, and for FY2023 is $75.68 billion.

### *4.3. Forecasting Energy consumption: ARIMA/ARMA model*

Table 3 exhibited the results of ARIMA/ARMA model for different orders that are estimated for total energy consumption (TEC) and its six sectorial components. Forecasting is done for the period from FY2018 to FY2023. TEC forecast also obtained by adding the forecasted values of its sectorial components. Forecast for FY2018 of TEC # (total energy consumption forecasted) is 51.2 billion from the sum of all forecasted values of its sectorial components, whereas 51.5 billion TEC* (sum of all sectorial components of energy consumption) is obtained from ARIMA/ARMA model of TEC*. There is no significant difference between these two forecasted values. However, there is a significant difference in forecasted values of TEC # for FY2023 from these two techniques (i.e., by using ARIMA/ARMA model to TEC # and sum of all forecasted values of its sectorial components), 56.8 billion forms applying ARIMA/ARMA model to TEC # whereas 63.6 billion for the sum of forecasted values of all sectorial components of TEC*. However, the forecasted GDP for FY2018 is $35.67 billion, and for FY2023 is $70.88 billion.

**Table 2**

**Component wise forecasted value of Energy Consumption by using the AR model**

| Period | TEC # | TEC* | **Components of Energy Consumption** | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | AEC | CEC | DEC | IEC | OGEC | TREC | GDP |
| FY18 | 52,876,235 | 52,768,946 | 756,746 | 2,032,294 | 11,781,102 | 18,652,289 | 1,389,429 | 18,157,085 | 36,534,101 |
| FY19 | 59,266,689 | 54,896,931 | 749,640 | 2,135,616 | 12,246,037 | 19,286,328 | 1,613,613 | 18,865,697 | 41,865,288 |
| FY20 | 60,179,654 | 56,005,355 | 742,858 | 2,276,158 | 12,561,082 | 19,464,221 | 1,704,290 | 19,256,747 | 48,276,578 |
| FY21 | 62,843,579 | 56,672,579 | 736,382 | 2,403,602 | 12,805,269 | 19,490,504 | 1,808,319 | 19,428,503 | 55,216,934 |
| FY22 | 65,131,015 | 57,642,028 | 730,198 | 2,559,661 | 12,953,513 | 19,344,724 | 2,600,647 | 19,453,285 | 63,540,187 |
| FY23 | 70,628,623 | 57,740,746 | 724,290 | 2,710,881 | 13,025,997 | 19,116,716 | 2,781,030 | 19,381,832 | 75,684,263 |
| **RMSE** | **0.1090** | | *0.0805* | *0.0317* | **0.0592** | *0.1597* | **0.2902** | **0.1426** | **0.0158** |
| **MAE** | **0.0988** | | *0.0698* | *0.0300* | **0.0495** | *0.0144* | **0.1351** | **0.2866** | **0.0150** |

*#: Forecasting of EC by using AR with seasonal dummies model; *: Sum of all sectorial components*

*Note: (all values are in.000)*

**Table 3**

## Component wise forecasted value of Energy Consumption by using ARMA/ARIMA model

| Period | TEC # | TEC* | **Components of Energy Consumption** | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | AEC | CEC | DEC | IEC | OGEC | TREC | GDP |
| FY18 | 51,226,513 | 51,547,460 | 644,939 | 2,053,541 | 11,829,744 | 18,465,236 | 1,290,016 | 17,263,984 | 35,673,057 |
| FY19 | 52,297,121 | 53,270,752 | 653,893 | 2,210,360 | 11,772,768 | 19,555,188 | 1,395,431 | 17,683,113 | 40,396,863 |
| FY20 | 52,861,993 | 54,816,400 | 697,980 | 2,359,071 | 11,716,260 | 19,918,143 | 1,521,190 | 18,603,755 | 46,141,559 |
| FY21 | 53,436,110 | 58,020,619 | 795,960 | 2,443,952 | 11,895,767 | 21,690,503 | 1,664,883 | 19,529,553 | 52,315,423 |
| FY22 | 56,224,203 | 61,030,307 | 638,859 | 2,555,803 | 12,446,059 | 23,056,726 | 1,876,558 | 20,456,303 | 59,750,257 |
| FY23 | 56,841,459 | 63,555,470 | 644,052 | 2,686,396 | 12,637,161 | 24,074,291 | 2,133,977 | 21,379,592 | 70,884,121 |
| RMSE | 0.1365 | | 0.1636 | 0.0485 | **0.0496** | 0.2503 | *0.1264* | *0.1402* | 0.0182 |
| MAE | 0.1255 | | 0.1418 | 0.0481 | **0.0402** | 0.2210 | *0.1336* | *0.1019* | 0.0151 |

*#: Forecasting of EC by using ARMA/ARIMA model; *: Sum of all sectorial components*

*Note: (all values are in. 000)*

## 4.4. Forecasting error – total energy consumption

To compare the forecasting errors, we estimated root mean square error (RMSE) and mean absolute error (MAE) for all data series, and compare the forecasting values of both models. The outcome of MAE and RMSE are exhibited in Table 2 and Table 3 for AR-model and ARIMA/ARMA model, respectively. Comparing forecasting errors, for TEC obtained from AR-model, has minimum RMSE and MAE, so for this series, AR-model gives better forecast as compare to ARIMA/ARMA. For sectorial components of TEC out of six sectorial components, forecasts obtained from AR-model three (AEC, CEC & IEC) gives a better forecast and for the other three (DEC, OGEC & TREC) sectorial components forecast from ARIMA/ARMA gives a better forecast.

## 4.5. Granger causality technique

One of the objectives of undertaken research is to examine the causal relationship between GDP and TEC with its components. The Granger causality test's basic condition is that the integrating order of both series should be the same [80]. From Table 1, by applying ADF test of a unit root, series TEC, AEC, DEC, and TREC are stationary at a level whereas CEC, IEC, OGEC, and GDP are stationary at the 1$^{st}$ difference. So we can apply the Granger causality test for the pairs: CEC & GDP, IEC & GDP, and OGEC & GDP. Form Table 4 results reveal that only one-way causality is established between IEC and GDP, and the direction is from IEC to GDP, for other combinations, we have not found any causal association amid pairs of economic indicators.

## 4.6. Toda & Yamamoto Wald technique

Toda-Yamamoto Wald test is applicable for all pairs of variables irrespective of the order of integration, since series TEC, AEC, DEC, and TREC are stationary at the level, whereas, CEC, IEC, OGEC and GDP are stationary at the 1st difference. Therefore, the Toda-Yamamoto Wald test is an appropriate technique for examining the causal association among a pair of variables [80]. Outcomes of Table 5 exhibited that unidirectional causality is confirmed between IEC and GDP, and the direction is from IEC to GDP, for other combinations, we have not found any causality between the pairs of variables.

**Table 4**

**Pairwise Granger causality tests**

| | | | |
|---|---|---|---|
| Lags: 1 | | | |
| Null Hypothesis: | Obs. | F-Statistic | Prob. |
| DLGDP does not Granger Cause DLCEC | 39 | 0.05527 | 0.8155 |
| DLCEC does not Granger Cause DLGDP | | 0.21494 | 0.6457 |
| DLGDP does not Granger Cause DLOGEC | 39 | 0.80903 | 0.3744 |
| DLOGEC does not Granger Cause DLGDP | | 1.49262 | 0.2297 |
| DLGDP does not Granger Cause DLIEC | 39 | 0.36246 | 0.5509 |
| DLIEC does not Granger Cause DLGDP | | 3.05749 | 0.0889 |
| Lags: 2 | | | |
| Null Hypothesis: | Obs. | F-Statistic | Prob. |
| DLGDP does not Granger Cause DLCEC | 38 | 0.12313 | 0.8846 |
| DLCEC does not Granger Cause DLGDP | | 0.34394 | 0.7115 |
| DLGDP does not Granger Cause DLOGEC | 38 | 0.9336 | 0.4033 |
| DLOGEC does not Granger Cause DLGDP | | 1.00503 | 0.3770 |
| DLGDP does not Granger Cause DLIEC | 38 | 1.82648 | 0.1769 |
| DLIEC does not Granger Cause DLGDP | | 1.82939 | 0.1764 |

**Table 5**

**Toda & Yamamoto causality technique**

| Null Hypothesis: | Chi-Square | P-value | Granger Causality |
|---|---|---|---|
| DLGDP does not Granger Cause LTEC | 3.3200 | 1.1901 | No |
| LtEC does not Granger Cause DLGDP | 0.8333 | 0.6592 | No |
| DLGDP does not Granger Cause LDEC | 0.9320 | 0.8046 | No |
| LDEC does not Granger Cause DLGDP | 0.8123 | 0.7115 | No |
| DLGDP does not Granger Cause LAEC | 2.0159 | 0.9403 | No |
| LAEC does not Granger Cause DLGDP | 2.1518 | 0.8770 | No |
| DLGDP does not Granger Cause LTrEC | 2.0159 | 0.9403 | No |
| LTrEC does not Granger Cause DLGDP | 0.9220 | 0.8846 | No |
| DLGDP does not Granger Cause DLCEC | 1.1251 | 0.5033 | No |
| DLCEC does not Granger Cause DLGDP | 0.9251 | 0.4770 | No |
| DLGDP does not Granger Cause DLOGEC | 0.8521 | 0.3769 | No |
| DLOGEC does not Granger Cause DLGDP | 0.9351 | 0.4764 | No |
| DLGDP does not Granger Cause DLIEC | 3.1124 | 1.1501 | No |
| DLIEC does not Granger Cause DLGDP | 5.1124 | 0.0501 | Yes |

## 5. Conclusions

The undertaken research aims to forecast economic growth (EG), and energy consumption (EC) of Pakistan for five fiscal years such as from FY2018 to FY2023 using two different time series techniques, also explore the causal association amid EC and, its sectorial EC, and economic growth (GDP). The undertaken research also analyzed the efficiency of both time series forecasting models such as ARIMA/ARMA and AR models. The outcomes of the conducted study established that the ARIMA/ARMA forecasting model offers more accurate forecasted values of total energy consumption of Pakistan. Since the integrating order of both TEC and GDP are different, we cannot apply the Granger causality test. Since the integrating order of CEC, IEC & OGEC, and GDP are the same, we use the Granger causality test, and the results of Granger causality demonstrated no causal association between CEC, OGEC & GDP variables. However, unidirectional causality is established between IEC and GDP, and the direction is from IEC to GDP. Thus, we have applied the Toda & Yamamoto Wald model because of the different integrating orders. Still, we have obtained similar results, and there is one-way causation from IEC to GDP. The policymakers while making effective environmental and energy policies, they must comprehend the association amid EG and EC. The previous data concluded that there is no specific agreement on the causative association of EC and EG. The outcomes of the undertaken study offer significant policy implications. The unidirectional causal association from industrial energy consumption (IEC) and economic growth (GDP) demonstrates that for a higher level of economic growth (EG), we need to have a higher level of industrial energy consumption (IEC). Hence, this confirms that industrial progress can lead to a higher level of economic growth. According to the results of energy forecasting from FY2018 to FY2023, it is inferred that there is a continuous increase in energy demand that also translated into economic growth (EG). Hence, it is concluded that the higher demand for energy consumption is due to Pakistan's rapid technical and economic development. Therefore, it is finally concluded that Pakistan has to increase the energy resources for sustainable economic growth.

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