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AI-Driven Prediction of Average Per Capita GDP: Exploring Linear and Nonlinear Statistical Techniques

Abstract: - Average per capita GDP income is an important economic indicator. Economists use this term to determine the amount of progress or decline in the country's economy. It is also used to determine the order of countries and compare them with each other. Average per capita GDP income was first studied using the Time Series (Box Jenkins method), and the second is linear and non-linear regression; these methods are the most important and most commonly used statistical methods for forecasting because they are flexible and accurate in practice. The comparison is made to determine the best method between the two methods mentioned above using specific statistical criteria. The research found that the best approach is to build a model for predicting Iraq's average GDP per capita income by relying on the amounts of average GDP per capita income in the past years (1981-2020). The researcher found that in a second way, it became clear that the non-linear regression model of the Asian model was the best model representing (average per capita GDP income) in Iraq, and this model was used to predict the period (20221-2027). When comparing the two methods of projected amounts up to 2027, it was found that the best method was the second based on the indicator mean absolute percentage error (MAPE) because he has the least value.

Keywords: Box - Jenkins method, Linear and non-linear regression, Average per capita GDP income of Iraq.

I.INTRODUCTION

The analysis and prediction of economic indicators, such as Gross Domestic Product (GDP) and its per capita counterpart, play a crucial role in understanding the trajectory of a nation's economic development. The per capita GDP, in particular, provides insights into the standard of living, economic growth, and overall well-being of a country's population. In this context, the focus of this study is on Iraq, a nation with a diverse socio-economic landscape, as it seeks to forecast the average per capita GDP using artificial intelligence for the period spanning from 2021 to 2027 [15].

Iraq, situated in the heart of the Middle East, has experienced a complex history characterized by periods of conflict, economic sanctions, and post-war reconstruction. These factors have exerted a substantial influence on the country's economic performance over the years. As Iraq continues to rebuild and stabilize its economy, accurate forecasts of key economic indicators are vital for policymakers, investors, and other stakeholders to make informed decisions. By leveraging statistical methods, this study aims to provide valuable insights into the potential trajectory of Iraq's per capita GDP in the coming years.

The forecasting of economic indicators, while inherently challenging due to the multitude of interplaying factors, has been greatly facilitated by advancements in statistical techniques and the availability of extensive economic data. Various time series analyses and econometric models have been developed to capture the underlying patterns and trends in economic data, enabling researchers and analysts to generate reasonably accurate forecasts.

In this study, we will employ a combination of statistical methods to forecast the average per capita GDP in Iraq using artificial intelligence for the period from 2021 to 2027. These methods may include time series analysis techniques such as autoregressive integrated moving averages (ARIMA) [7], exponential smoothing (ETS), and potentially more advanced models like vector autoregression (VAR) or machine learning-based approaches. By utilizing historical data on Iraq's economic performance, along with relevant external factors such as global

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economic conditions, commodity prices, and geopolitical influences, we aim to develop a comprehensive forecasting model that captures the dynamics of Iraq's economic landscape.

The implications of accurate per capita GDP forecasts extend beyond theoretical insights; they hold practical significance for policy formulation, resource allocation, and long-term planning. This study seeks to contribute to the existing body of knowledge by offering a data-driven perspective on the potential trajectory of Iraq's economic growth, helping decision-makers navigate the challenges and opportunities that lie ahead.

In conclusion, this research endeavour aims to forecast the average per capita GDP in Iraq using artificial intelligence for the years 2021 to 2027 through the application of diverse statistical methods. By combining historical economic data and contemporary influences, this study seeks to shed light on the possible trajectory of Iraq's economic development and provide insights that can inform critical decision-making processes.

1.1. Problem and Search Goal

The lack of future data on national income amounts in Iraq does not help decision-makers from the top to develop economic policy, choose appropriate economic models, and solve some of the issues experienced by the national economy, such as inflation, unemployment, and many other economic problems, and identify the economic sectors that should be focused later on in future plans that fit the expected values.

The research aims to study average per capita income using two statistical methods; This is followed by the prediction of the coming years through the above methods and then the choice of the best of them based on the statistical MAPE absolute average error criterion. The forecast figures provide very large services to decision-makers in the senior leadership to prepare strategic plans and programs and guide future plans on the use of available resources and other non-oil sectors to increase national income and thus increase the level of well-being of Iraqi citizens.

1.2. Objective of Research

In his research, the researcher aims to obtain future predictions of average per capita national income at the public and private sector levels through the use of two statistical methods: the classic method of linear and non-linear general trend models and the method of box-Jenkins models and the trade-off between them using the criteria of the trade-off between models.

II.TIME SERIES MODELS

Specialists have developed several mathematical models that link the values of views, and the values of different vehicles of the time series. Before mentioning some of these models, the following symbols used in the time series will be defined. The symbol (T) is used to indicate the general direction, the symbol (S) on the seasonal vehicle, the symbol (C) on the rotating vehicle, and the symbol (I) on the accidental changes. One of the most prominent mathematical models describing the time series is the aggregator and the multiplication model [14].

2.1 Additive Model

In this model, it is assumed that the values of the phenomenon in a given period of time are the Y_t product of the collection of the four compounds that make up the chain at the same time, each expressed in numerical value and as follows [5]:

$$Y_t = T_{t+} S_{t+} C_{t+} I_t \qquad (1)$$

2.2 Multiplicative Model

In this model, it Y_t is assumed that the values of the phenomenon in a certain period of time are the product of multiplying the four compounds that make up the chain at the same time with the assurance of a numerical value, and (S,C,I) percentages and shall be as follows:

$$Y_t=T_t \text{ x } S_t \text{ x } C_t \text{x } I_t \qquad (2)$$

2.3 Trend Analysis

"The general direction vehicle is one of the most important vehicles that illustrate the march of the chain in general and over a long period where it reflects the development in many phenomena (increase or decrease) over time, and has two types" [2]:

2.3.1. *Linear Trend*

In other words, the values of the phenomenon tend to increase continuously or decrease continuously, then the equation of the general direction can be represented to be in the form of a straight-line equation and its formula is:

$$Y_t = B_0 + B_1 * t \qquad (3)$$

2.3.2. *Nonlinear Trend*

"If the trend of the values of the phenomenon is to increase for a long time and then gradually shift towards decrease then it represents a curve that reflects the direction of this change, it means that the phenomenon takes a non-linear form as in economic phenomena characterized by long-term change and from the types of the equation of the general non-linear trend" [2]:

2.3.3. *Quadratic Trend*

In other words, time series data show a second-degree curved relationship (parabola) through the time series chart and its formula is:

$$Y_t = B_0 + B_1 * t + B_2 * t^2 + \in_t \qquad (4)$$

2.3.4. *Exponential Trend*

"Here, the data take an unfortunate general trend over a long-term time and its formula is" [2]:

$$Y_t = B_0 B_1^t \qquad (5)$$

III.METHODS OF TREND ESTIMATING

The parameters of the equation of the general direction of any phenomenon are estimated in many ways, and the most important methods to be used in this study are:

3.1 Average Per Capita National Income

In economic thought, "average per capita real income "average per capita national income or real GDP average has traditionally been used as a key indicator used to measure development and the degree of economic progress. This indicator represents the fact that the average per capita national income or GDP is divided by the population. Therefore, calculating the average per capita real national income involves estimating the per capita share of goods and services in one country and comparing it with those of individuals in other countries. Gross national income calculates the value of goods and services from locally owned resources" [13].

Despite criticism seeking to use average per capita national income or average per capita national income as an indicator of economic growth, its use will do the same in this research because it is unclear that there are other quantitative measures that can be based exclusively as model measures of economic growth, and that it remains the most acceptable indicator for countries, economic systems, and economists.

3.2 The Importance of Average Per Capita National Income

"This indicator, along with other indicators, reflects the volume of economic activity, so it is of interest to all countries for several things:

1. Summarizes the total activities that occurred for economic activities belonging to a country during a given period, often one (year).

2. It is an important indicator for analyzing and evaluating economic performance and monitoring developments in macroeconomic theory and development plans and policies.

3. The image shows consumption trends for key activities when calculated in a spending manner.

4. Summarizes the returns that production elements have received as a result of their contribution to local production.

5. GDP is an important measure of production and level of production because it largely determines how much a country can consume.

6. Use it as an indicator of comparison between countries in terms of determining the economic level of the state where levels of GDP or average per capita are used by international organizations to determine the eligibility of countries to receive loans or assistance or to determine the conditions under which loans, aid or funds are granted" [13].

3.3 Description of Average Per Capita Income Data

The time series to be studied contains data representing the value of the average per capita national income (in 1 million dinars) for the period from 1980 to 2020, as shown in Table (1).

Table 1. Shows the values of average per capita gross national income, the atlas method (at current US Dollar prices) for the period (1980-2020) and the value of the index code NY.GNP.PCAP.CD

Average per capita gross national income at current prices Dollar	The year	No	Average per capita gross national income at current prices Dollar	The year	No
1730	2001	22	3910	1980	1
1420	2002	23	3420	1981	2
850	2003	24	3010	1982	3
1370	2004	25	2350	1983	4
1430	2005	26	2540	1984	5
1820	2006	27	2760	1985	6
2400	2007	28	3060	1986	7
3550	2008	29	3540	1987	8
4160	2009	30	3730	1988	9
4580	2010	31	3730	1989	10
4960	2011	32	7070	1990	11
6310	2012	33	70	1991	12
7050	2013	34	50	1992	13
6750	2014	35	40	1993	14
5800	2015	36	60	1994	15
5340	2016	37	130	1995	16
4670	2017	38	390	1996	17
4840	2018	39	750	1997	18
5490	2019	40	920	1998	19
4660	2020	41	1290	1999	20
			1600	2000	21

Source (data, 2022)**:**
https://data.albankaldawli.org/country/%D8%A7%D9%84%D8%B9%D8%B1%D8%A7%D9%82.

To find out the descriptive features of the data in the period mentioned, where the average per capita gross national income (3014.630) dollar and the highest value recorded (7070) for the year (1990), the lowest value recorded (40) dollar for the year (3991), and the dispersion of chain values from their average by a standard deviation of (2014.085), which gives an idea of the heterogeneity of string values, so the natural logarithm of the values was taken and then graphed, by representing them on the horizontal axis and the data values of the

output on the vertical axis, as in figure (1) in the index, in which a positive general direction appears to increase over time.

Figure 1. Chart the series after taking the first difference of data Average per capita gross national income for 1980-2020

3.4 Determining the Overall Trend Model of Average GDP Data

To determine the appropriate overall trend model for natural logarithm data for average per capita income of gross national income, we reconcile the general trend models (linear model, quadratic model and exponential model) and then trade them off to choose the best model based on forecast accuracy criteria.

Table 2. Values of the accuracy criteria for reconciling the overall trend models of average per capita data Gross National Income 1980-2020

Sig	F	R^2	MAPE	**Model**	**Function**
0.005	9.075	0.189	562.44630	$Y_t = -149612.544 + 76.314 \times t$	**Linear**
0.005	8.997	0.187	563.25330	$Y_t = -1153021.671 + 152092.330 \times \mathrm{Ln}(t)$	**Logarithmic**
0.040	4.506	0.104	313.41450	$Y_t = 791.888 \times 1.0390^t$	**Exponential function**

By comparison, the basic general trend model is the best model of all linear and non-linear models because MAPE has less predictive accuracy than other models, As in Fig. 2 in the index.

IV.ANALYSIS OF TIME SERIES USING BOX-JENKINS MODELS FOR AVERAGE

Per Capita GDP Data

After collecting data, which is the first phase of the application process of the Box-Jenkins methodology, the stability of the series is defined, the appropriate model rank is determined, the parameters of that model are assessed, their morale is tested, as well as the model's validity test, and the model is used to predict.

4.1 Results

The results of the Ducky Fuller extended test for series data of this research as shown in Fig. 3 in the index. Then after tha,t we found the results of the Ducky Fuller extended test for series data as in Table (3).

Table 3. Results of the Ducky Fuller Extended Test for Series Data

Model	Estimated Value	Test Statistic	P-Value
Test Without constant	-0.06047	-1.04959	0.26020
Test With Constant	-0.19596	-2.00023	0.28560
With Constant and Trend	-0.26531	-2.50429	0.32450

According to the results above, we calculate (AFC and PAFC) for the average per capita income at current prices of national income as in Fig. 4 in the index.

Then to achieve stability, the first differences were taken to reach the stability of the time series as shown in Fig. 4, drawing both the self-bonding functions (ACF) and the partial self-association (PACF) as shown in Fig. (1) as follows:

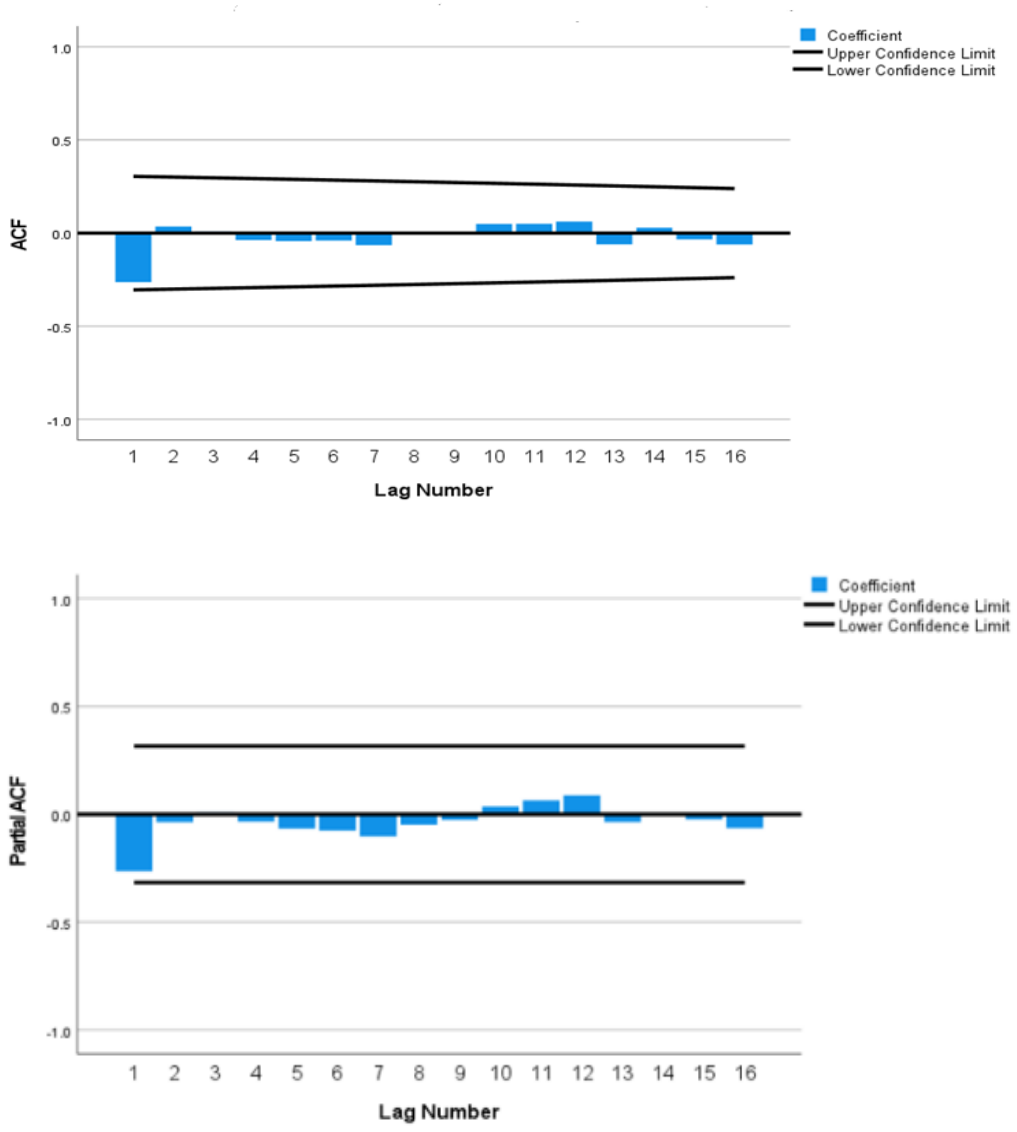

Figure 2. Chart the series after taking the first difference of data Average per capita gross national income for (1980-2020) (AFC, PAFC)

We note that the series has become stable and that the results of dickey-Fuller Augmented stability test after taking the first difference in the time series of all P-Value values are less than 0.05) for the three models (test without counting fixed, test with fixed calculation, test with constant calculation and general trend) as indicated in table (4).

Table 4. Results of the Extended Ducky FullerTest after taking the first difference to series data

Model	Estimated Value	Test Statistic	P-Value
Test Without constant	-1.26548	-8.06336	1.208e-014
Test With Constant	-1.26645	-7.96329	5.032e-008
With Constant and Trend	-1.27874	-7.92154	9.483e-008

We determine the rank of the model by conciliation of a number of models and choose the best model according to the trade-off criteria (AIC, H-Q, SBC) table (5) shows the proposed models and the value of the trade-off criteria.

Table 5. Represents the proposed Box Jenkins models for series data and trade-off criteria.

Model	AIC	H-Q	SBC	P-value
ARIMA(1,1,0)	691.82430	693.65620	696.89090	0.085
ARIMA(0,1,1)	691.81670	693.64870	696.8834	0.07929
ARIMA(1,1,1)	691.80110	693.63310	696.86780	0.08646 0.82371
ARIMA(2,1,0)	691.80110	693.63310	696.86780	0.08646 0.82371
ARIMA(0,1,2)	693.77790	696.22040	700.53340	0.08434 0.84281
ARIMA(1,1,2)	694.63000	697.68330	703.07440	0.95580 0.87786 0.92983
ARIMA(2,1,1)	693.79380	696.23630	700.54930	0.82582 0.86100 0.90326
ARIMA(1,2,2)	696.60900	700.27280	706.74220	0.88484 0.84614 0.94394 0.91388

Table 5 above shows that the best model of Box Genkan's models to predict the value of average per capita national income is ARIMA (1,1,1) because the trade-off criteria values (AIC, H-Q, SBC) used to trade-off Different models are the lowest value among all the criteria values for other proposed models and table 6 shows the parameters of the model and the morale of these features where the parameters of the model are estimated according to the method of the greatest possibility seized:

Table 6. Represents the Estimated Parameter Value And Morale Of Series Data

	Coefficient	Std. Error	Z	p-value
$\theta 1$	-0.260792	0.151382	-1.72270	0.07929*

The ARIMA estimated model (1.1.1) is as follows:

$$y_t = y_{t-1} - y_{t-2} - 0.260792\, a_{t-1} + a_t$$

After the diagnosis and assessment of the model, the appropriateness and efficiency of the model must be confirmed and done through:

Drawing the functions of self-association and the functions of partial self-association of the parading trumpets shown in figure (2) conclude that all self-association factors and partial self-association of the trumpets fall within the limits of confidence, i.e. the series of condoms is random, indicating that the model is good, efficient and predictable.

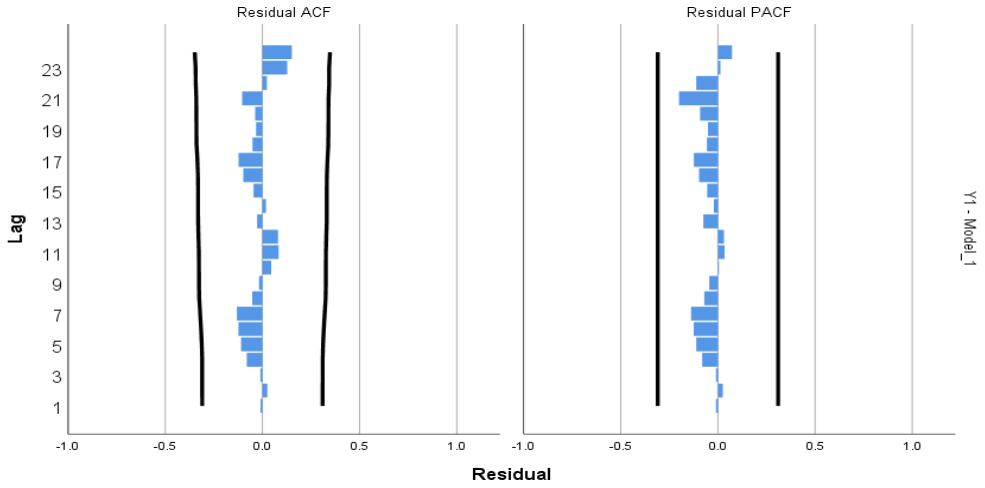

Figure 3. Chart the series after taking the first difference of data Average per capita gross national income for (1980-2020) (Residual AFC, Residual PAFC)

To be sure, the Ljung-Box, which is based on the condom, was conducted to examine the suitability of the model and the results were shown as follows:

$$\text{Ljung-Box Q' = 5.792}$$

$$\text{with p} - \text{value} = \text{P(Chi} - \text{square(18)} > 11.4554) = 0.994$$

We note that (Q= 11.4554) at k=9 displacement is less than the value (Chi-square) of scheduling and with a degree of freedom (8) and a moral level (0.05) equal to (15.5073) we must accept the hypothesis of nothingness:

$$H_0: r_i(a) = r_1(a) = r_2(a) \ldots = r_K(a) = 0$$

That is, errors are not linked to each other. Model	Number of Predictors	Model Fit statistics	Ljung-Box Q(18)		
		MAPE	Statistics	DF	Sig.
Average per capita national income, atlas method (current US dollar prices)	1	345.459	5.792	17	.994

4.2 Comparison of Models Used In Research For Average Per Capita National Income Data

By reconciling the general trend models (classical method) of data, it was shown that the best model among them was the Aces model, and by comparing the two methods based on the value of the forecast accuracy standard (MAPE) of the data, we note that ARIMA method is the best way to predict the average per capita national income. This is because the value of the forecast accuracy standard is lower than the other functions, as shown in Table No. (7):

Table 7. MAPE values for the basic general trend model and ARIMA model) (1,1,1) average per capita national income

MAPE	Model	Function
562.44630	$Y_t = -149612.544 + 76.314 \times t$	**Linear function**
563.25330	$Y_t = -1153021.671 + 152092.330 \times \mathrm{Ln}(t)$	**Logarithms'**
313.41450	$Y_t = 791.888 \times 1.0390^t$	**Exponential function**
345.45900	$y_t = y_{t-1} - y_{t-2} - 0.260792\, a_{t-1} + a_t$	**Box - Jenkins**

From Table 6, we note that the MAPE value for the exponential function model is lower than the ARIMA Box Jenkins model (1,1,1) so the exponential function trend model is more appropriate and Efficient, so the predictions obtained from the exponential function model are adopted as shown in table 8, and figure 4 shows the time chain of predicted values for the duration of (2021-2027).

Table 8. Predicted values and confidence limits for average Gross national income per capita for 2021-2027.

Year	Forecast	95% interval	
		Lower	Upper
2021	3944.46534	217.82991	71426.40353
2022	4098.18076	224.10382	74943.32677
2023	4257.88644	230.46117	78666.60177
2024	4423.81584	236.89994	82609.33452
2025	4596.21149	243.41807	86785.50452
2026	4775.32538	250.01344	91210.02496
2027	4961.41932	256.68392	95898.80711

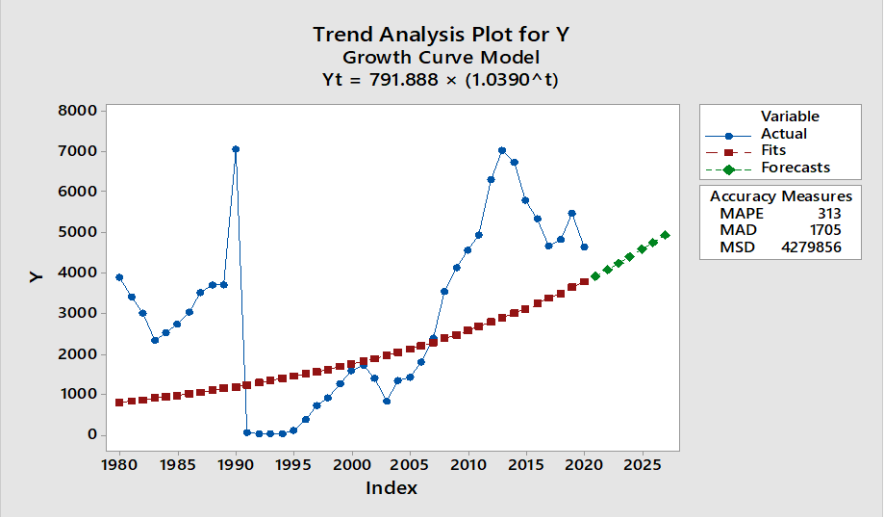

Figure 4. Chart of the series to show the predictive values of average per capita national income for the period 2021-2027

From the figure above, we note the predictive values of average per capita gross national income that are experiencing an escalation in growth over time, and this is what we have been observing recently in the continued rise in world oil prices to twice as high as in the previous two years.

V.CONCLUSIONS

Through the practical aspect of the analysis of time series using the classic style and the style of Box-Jenkins a number of results were reached and these results were as follows:

1) A positive general trend in the time series data for average per capita income of gross national income, and after reconciling different general trend models (linear, square, exponential) found that the basic general trend model is the best appropriate model of time series data by caliper for the average relative absolute error (MAPE).

$Y_t = 791.88 \times 1.0390^t$

2) The time series was unstable around the contrast as well as unstable around the average, so he took the natural logarithm of the time series and took the first difference to stabilize the variability and the average, and the stability was confirmed by the conduct of the extended Doki Fuller time series test and the p-value results for the test and in all versions were less than (0.05) and this indicates that the series has become stable.

3) ARIMA (1,1.1) appeared to be the best model among the Box-Genknzel models, based on trade-off criteria to choose the best model $(\mathrm{H}-\mathrm{Q}, \mathrm{SBC}, \mathrm{AIC})$

4) ARIMA (1,1.1) Ginkzel data on average per capita national income was moral according to the trumpet test (Ljung-Box Q' test) which shows that errors are random.

5) By comparing MAPE between the main general trend model (classical method) and the Box-Jenkins ARIMA model (1,1,1,1) The average per capita income of national income showed that the overall Asian trend model was better for having the lowest values of these standards, so it was It's going to be used in the forecasting process.

6) Predictions of average per capita gross national income (2021-2027) using the overall trend model showed that there was a clear upward growth in average per capita national income.

7) A positive general trend in the time series data for average per capita income of gross national income, and after reconciling different general trend models (linear, square, exponential) found that the basic general trend model is the best appropriate model of time series data by relative average error (MAPE).

$Y_t = 791.888 \times 1.0390^t$

8) The findings shown in Table 15 showed that the average per capita income of gross national income for the forecast period (2021-2027) increased from (3,944,465) U.S. dollars for 2021 to (4,961.41) USD for 2027, indicating a rise in Average per capita income of gross national income.

VI.RECOMMENDATIONS

1. The use of other methods of time series in the forecasting field and comparison with the methods used in our research.

2. We recommend that we take advantage of the results of this research from relevant authorities for adopting the scientific method, especially with regard to forecasting, to help develop plans, policymaking good decisions and make appropriate decisions.

3. Future studies can be conducted, including the use of time series models to predict the average per capita income of gross national income as well as economic activities, which are of great importance to identify activities that are experiencing growth, decline or stagnation in their contribution to the average per capita Iraqi national income for the coming period to clarify the visions of decision makers and economic analysts to promote the economic development of the country.

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