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Modeling and Forecasting Egyptian GDP: Autoregressive-Integrated Moving-Average Model

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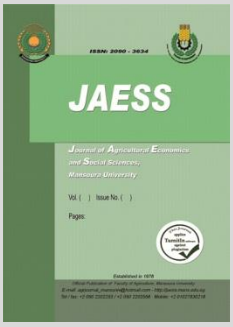

ABSTRACT

The Gross Domestic Product (GDP) is the total worth of all goods and services produced within a country's boundaries in a given year. It has become the single best indicator of economic growth. GDP per capita, on the other hand, correlates closely with the living standard trend through time. Prior studies have only relied on a yearly series when analyzing and forecasting Egypt's GDP. In this work, the appropriate Autoregressive-Integrated Moving-Average (ARIMA) model for the Egyptian GDP data was built using the Box-Jenkins approach (BJ). The BJ methodology follows a four-step procedure: Identification, Estimation, Diagnostic Checking, and Forecasting. Quarterly GDP data for Egypt was obtained from the Ministry of Planning and Economic Development (MPED) for the fiscal years (2001/02-2020/21). The results indicate that ARIMA (3,1,3) is the most appropriate model, considering model selection criteria. Furthermore, goodness-of-fit tests were performed to confirm that the model is well calibrated. The forecasted estimates suggest that Egyptian GDP will continue to rise as long as there are no serious swings in the economy over the forecast period. These findings can be used to aid policymakers in directing future planning and development. Looking forward, further attempts could prove quite beneficial to the literature.

Keywords: Gross domestic product; Quarterly series; Autoregressive-Integrated Moving-Average model; Box-Jenkins approach; Egyptian economy.

INTRODUCTION

Today, a substantial portion of the work in applied economic analysis for large businesses and governments involves forecasting the future path of important macroeconomic indicators such as Gross Domestic Product (GDP), inflation, and unemployment to adjust policies more effectively. Forecasts assist politicians who want the information to make sound policy decisions. Not much theoretical study addresses the selection of models, accuracy, or other issues linked to GDP forecasting.

GDP is commonly used to measure economic progress. It is primarily recognized as the world's most effective indicator of national development (Lepenies, 2016). A country's GDP is the total monetary worth of the ultimate goods and services created within a particular country over a specific period (Mankiw, 2016). According to Todaro & Smith (2012), it also plays a significant role in establishing a country's human development index, acting as the benchmark for measuring its progress.

Egypt's GDP at market prices was L.E. 6.34 trillion in 2020/21, up from L.E. 5.86 trillion in the previous year (MPED,2022). Egypt's economy continued to develop at a healthy rate of 3.3 percent in 2020/21 and 3.6 percent in 2019/20, making it one of the few countries to have positive economic growth throughout the coronavirus pandemic. At the sectoral level, agriculture contributes around 11.57 percent to the GDP, 32.01 percent comes from industry, and 51.76 percent from services.

The most recent systematic study on analyzing and forecasting Egypt's GDP was carried out in 2019 by Abonazel and Abd-Elftah. They adopted the Box-Jenkins approach to fit the suitable ARIMA model within the period (1965–2016). Their work concluded that ARIMA (1,2,1) is the most fitted model. Similarly, the same approach was adopted by Eissa (2020) to forecast GDP per capita in Egypt based on the time series for the period (1960–2018). It concluded that ARIMA (1,1,2) is the most precise model.

The main objective of this work is to identify a general model to forecast quarterly GDP for Egypt. A seminal contribution by Box and Jenkins (1970) identified a procedure for time series forecasting, namely: Autoregressive Integrated Moving Average (ARIMA). It includes identification, estimation, and checking. Although this method is well-known in the broad literature, it is still rare in Egyptian studies (Eissa,2020). The quarterly data from MPED for fiscal years (2001/02-2020/21) was used. This study is the first to deal with analyzing and forecasting quarterly GDP in the Egyptian setting.

The model results are encouraging and show that ARIMA (3,1,3) is the most convenient specification on a quarterly series basis, considering model selection criteria and diagnostic tests. These results are a good indication for policymakers in the private and public sectors.

There are three parts to this paper. The first section presents the Box-Jenkins ARIMA modeling approach. The results are discussed in the next section. In the final part, some conclusions are drawn.

Methodology

The objective is to validate an ARIMA model to analyze and forecast quarterly GDP series. The quarterly data was obtained from the Ministry of Planning and

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Economic Development (MPED) for fiscal years (2001/02-2020/21). Box-Jenkins's ARIMA model was applied using EViews12. The ARIMA models are flexible and commonly used in univariate analysis (Hassan et al., 2020). It is made up of three processes: the autoregressive process (AR), the differencing process (d), and the Moving Average Process (MA) (Gujarati & Porter, 2009).

The Autoregressive (AR) Model

The following is an AR(p) model

$$Y_t = B_0 + B_1 Y_{t-1} + B_2 Y_{t-2} +, \ldots, B_p Y_{t-p} + u_t$$

Where

u_t denotes a white noise error term.

The Moving Average (MA) Model

Y_t can also be modeled as the MA(q) model, a weighted or moving average of the current and past white noise error terms:

$$Y_t = C_0 + C_1 u_t + C_2 u_{t-1} +, \ldots, C_j u_{t-q}$$

The Autoregressive Moving Average (ARMA) Model

The ARMA (p,q) model combines AR and MA terms.

The Autoregressive Integrated Moving Average (ARIMA) Model

The Box–Jenkins (BJ) methodology assumes that the underlying time series is stationary or can be made stationary by differencing it one or more times. This is known as the ARIMA (p, d, q) model, where d denotes how many times a time series must be differenced to make it stationary. Figure (1) shows the visual operation flow of the ARIMA modeling and forecasting steps.

The BJ methodology follows a four-step procedure:

Step 1: Identification

Determine the appropriate values of p, d, and q. The correlogram and partial correlogram are the primary tools in this search.

Step 2: Estimation

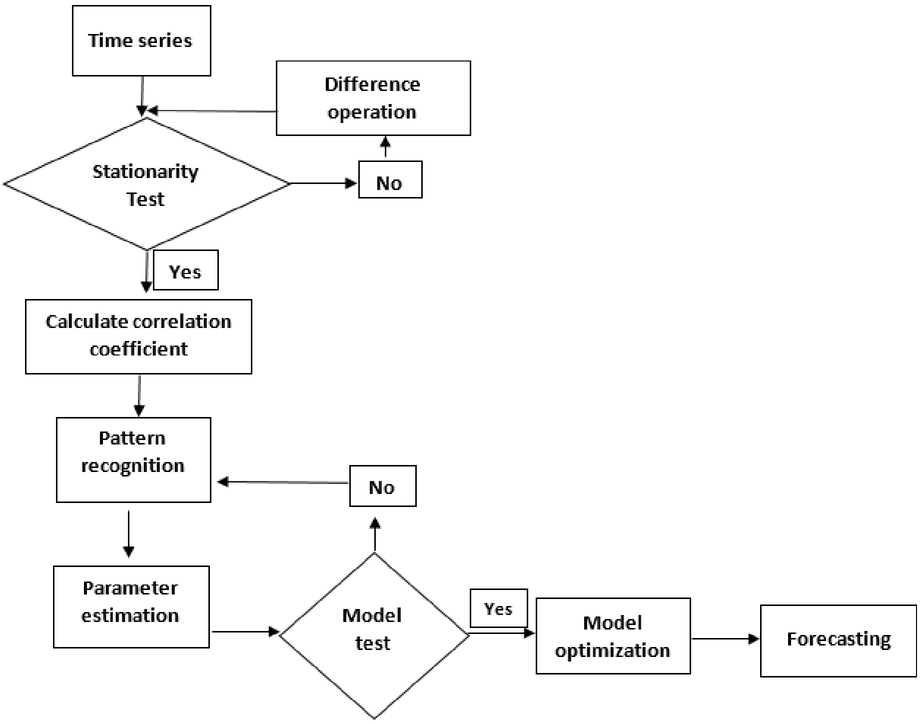
Calculate the parameters of the selected model.

Step 3: Diagnostic Checking

Examine the residuals from the fitted model to see if they are white noise. The chosen model is accepted if they are; if not, start over. As a result, the BJ methodology is iterative.

Step 4: Forecasting

The forecasting performance of an ARIMA model, both within and outside of the sample period, is the crucial test of its success.



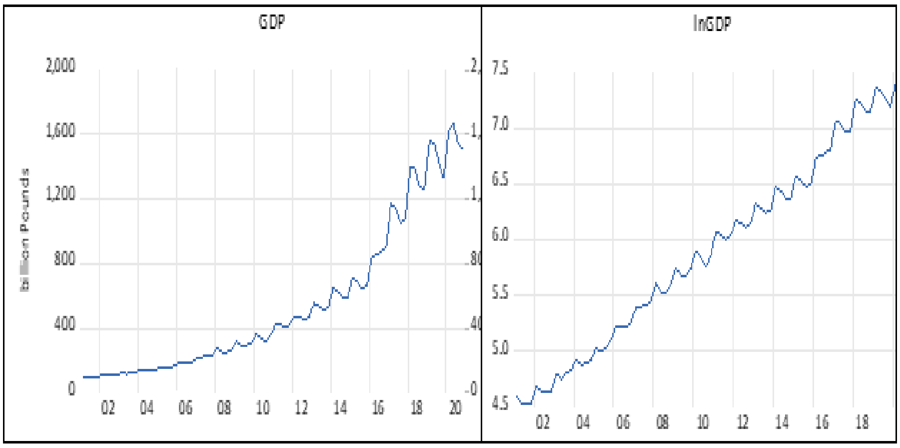
Source: Ma *et al.* (2018).

Figure 1. ARIMA modeling and forecasting.

RESULTS AND DISCUSSION

Following the widely used methodology, the present paper aims to fit a convenient Box-Jenkins's ARIMA model using quarterly data, with the ultimate aim of providing a forecast for the upcoming five years. The first step in analyzing and forecasting any time series is the visual inspection of the graph to determine the characteristics of the time series. Figure (2) depicts the plots of the GDP series in market prices and its logarithmic form.

The time plots indicate that Egyptian GDP is not a stationary series. Moreover, the non-stationary behavior is confirmed by two widely used unit root tests: the Augmented Dickey-Fuller (ADF) and the Phillips-Perron (PP). The first-order difference ensures that the series is stationary, lnGDP ~ I (1) (Table (1)).



Source: Author's calculations.

Figure 2. Egypt's GDP from 2001/02 to 2020/21

Table 1. Unit root tests output

Variables	Level Form			First Difference		
	Intercept	**Trend and intercept**	**None**	**Intercept**	**Trend and intercept**	**None**
			Augmented Dickey-Fuller (ADF)			
GDP	2.299	0.133	2.820	-1.312	-3.188	-0.322
lnGDP	-0.154	-3.819**	2.397	-3.640**	-3.593**	-0.913
			Phillips-Perron (PP)			
GDP	1.182	-1.892	3.282	-9.572**	-11.806**	-9.219**
lnGDP	-0.051	-6.303**	6.238	-13.595**	-13.422**	-9.724**

Note: ** indicates a 5 percent significance level.
Source: Author's calculations.

After establishing that the first difference in the series is stationary, the following step is to determine the order of the autoregressive process (P) and the order of the moving average process (q). EViews software includes an automatic ARIMA forecasting series technique, enabling the user to accurately determine an appropriate ARIMA specification (Table (2)).

Table 2. Model Selection Criteria.

Dependent Variable: D(LGDP)				
Model	**LogL**	**AIC***	**BIC**	**HQ**
(3,3)	160.378	-3.858	-3.618	-3.762
(3,4)	160.517	-3.836	-3.566	-3.728
(4,3)	160.505	-3.836	-3.566	-3.727
(4,4)	161.475	-3.835	-3.535	-3.715
(4,1)	155.337	-3.755	-3.545	-3.671
(4,2)	155.440	-3.733	-3.493	-3.637
(4,0)	153.179	-3.726	-3.546	-3.654
(3,2)	150.031	-3.621	-3.411	-3.537
(3,1)	144.757	-3.513	-3.333	-3.441
(2,4)	136.727	-3.259	-3.019	-3.163
(2,3)	131.465	-3.151	-2.941	-3.067
(3,0)	122.111	-2.965	-2.815	-2.905
(2,2)	121.121	-2.914	-2.734	-2.842
(0,4)	115.396	-2.770	-2.590	-2.697
(1,4)	115.514	-2.747	-2.537	-2.663
(1,3)	109.349	-2.616	-2.436	-2.544
(0,3)	103.357	-2.490	-2.340	-2.430
(2,1)	101.601	-2.446	-2.296	-2.386
(2,0)	93.522	-2.266	-2.146	-2.218
(0,2)	89.998	-2.177	-2.057	-2.129
(1,2)	90.353	-2.161	-2.011	-2.101
(1,1)	88.252	-2.133	-2.013	-2.085
(0,1)	86.404	-2.112	-2.022	-2.075
(0,0)	76.500	-1.886	-1.826	-1.862
(1,0)	77.334	-1.882	-1.792	-1.846

LogL: Maximum Likelihood parameter; AIC: Akaike information criterion; SC: Schwarz information criterion; HQ: Hannan-Quinn information criterion.
Source: Author's calculations.

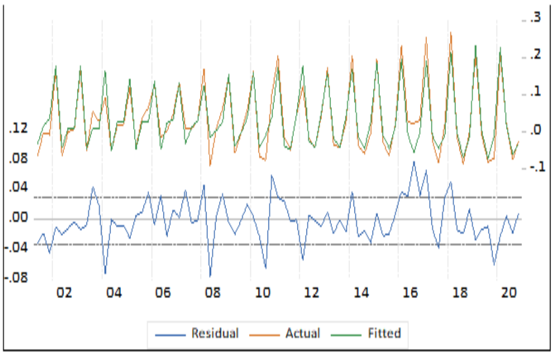
Although the appropriate ARIMA model was selected based on the least Akaike Information Criteria (AIC) and Schwarz information criterion (SIC) values, testing the parameter significance and the residual randomness of the estimated result is necessary to confirm selecting the optimal model. Accordingly, ARIMA (3,1,3) successfully passes the selection criteria.

Furthermore, goodness-of-fit tests were performed to confirm that the model is well calibrated (Table (3)). Figure (3) confirms the findings of fitting the model to the D(lnGDP) data by comparing the actual and fitted values, demonstrating that the model has a good fitting effect.

Table 3. Estimation results of ARIMA (3,1,3) model.

Dependent Variable: D(LGDP)				
Variable	**Coefficient**	**Std. Error**	**t-Statistic**	**Prob.**
C	0.037	0.003	0.000	0.000
AR(1)	-0.974	0.017	0.000	0.000
AR(2)	-0.973	0.019	0.000	0.000
AR(3)	-0.994	0.010	0.000	0.000
MA(1)	0.983	0.119	0.000	0.000
MA(2)	0.870	0.129	0.000	0.000
MA(3)	0.686	0.101	0.000	0.000
SIGMASQ	0.001	0.000	0.000	0.000
R-squared	0.893	Mean dependent variable	0.034	
Adjusted R-squared	0.883	S.D. dependent variable	0.092	
S.E. of regression	0.032	Akaike info criterion	-3.858	
Sum squared residuals	0.071	Schwarz criterion	-3.618	
Log likelihood	160.377	Hannan-Quinn criterion	-3.762	
F-statistic	84.806	Durbin-Watson statistic	1.847	
Prob(F-statistic)	0.000			

Source: Author's calculations.

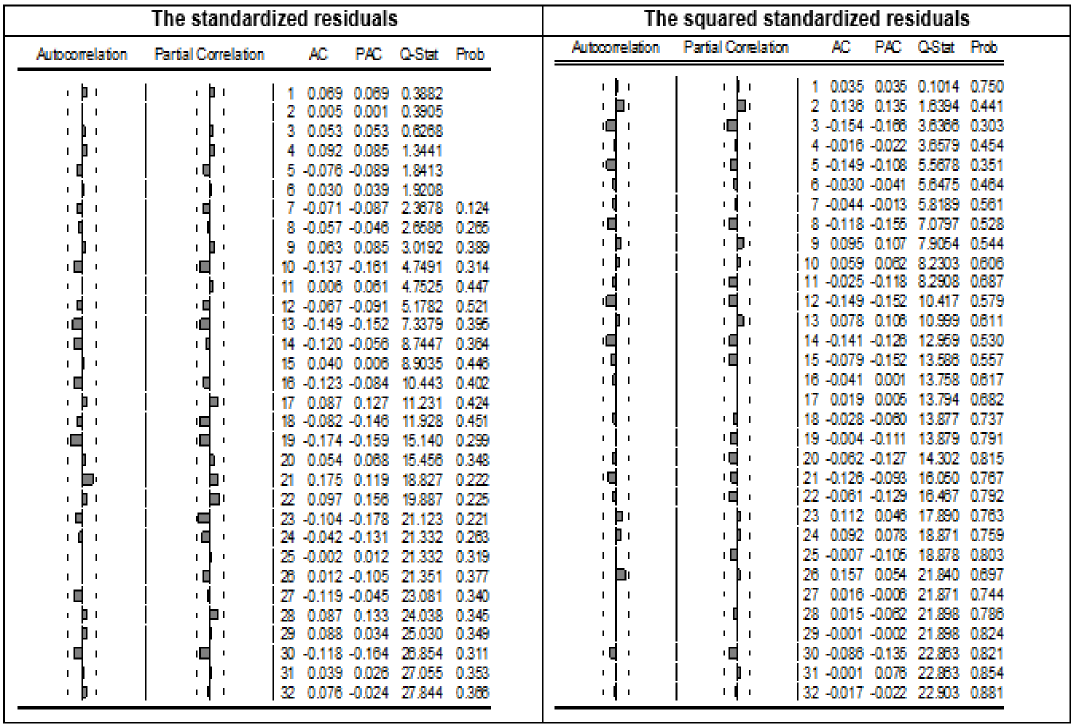


Source: Author's calculations.

Figure 3. Actual series, fitted series, and residual series of the DlnGDP sequence.

To further ensure the model adequacy, the correlogram (autocorrelations and partial autocorrelations) of the standardized residuals and the squared standardized residuals is depicted in Figure (4), confirming that the residual is white noise.

The Jarque-Bera statistic is insignificant, implying that the standardized residuals are normally distributed (Figure (5)).



The standardized residuals

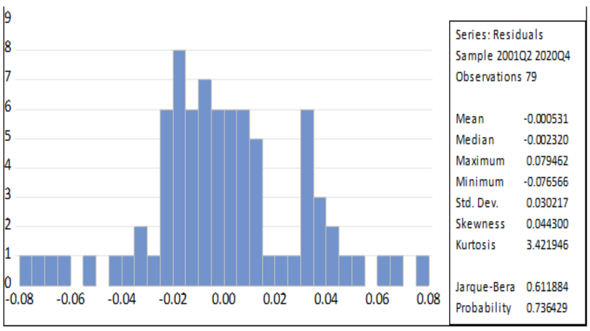
	AC	PAC	Q-Stat	Prob
1	0.069	0.069	0.3882	
2	0.005	0.001	0.3905	
3	0.053	0.053	0.6268	
4	0.092	0.085	1.3441	
5	-0.076	-0.089	1.8413	
6	0.030	0.039	1.9208	
7	-0.071	-0.087	2.3678	0.124
8	-0.057	-0.046	2.6586	0.265
9	0.063	0.085	3.0192	0.389
10	-0.137	-0.161	4.7491	0.314
11	0.006	0.061	4.7525	0.447
12	-0.067	-0.091	5.1782	0.521
13	-0.149	-0.152	7.3379	0.395
14	-0.120	-0.056	8.7447	0.364
15	0.040	0.006	8.9035	0.446
16	-0.123	-0.084	10.443	0.402
17	0.087	0.127	11.231	0.424
18	-0.082	-0.146	11.928	0.451
19	-0.174	-0.159	15.140	0.299
20	0.054	0.068	15.456	0.348
21	0.175	0.119	18.827	0.222
22	0.097	0.156	19.887	0.225
23	-0.104	-0.178	21.123	0.221
24	-0.042	-0.131	21.332	0.263
25	-0.002	0.012	21.332	0.319
26	0.012	-0.105	21.351	0.377
27	-0.119	-0.045	23.081	0.340
28	0.087	0.133	24.038	0.345
29	0.088	0.034	25.030	0.349
30	-0.118	-0.164	26.854	0.311
31	0.039	0.026	27.055	0.353
32	0.076	-0.024	27.844	0.366

The squared standardized residuals

	AC	PAC	Q-Stat	Prob
1	0.035	0.035	0.1014	0.750
2	0.136	0.135	1.6394	0.441
3	-0.154	-0.166	3.6366	0.303
4	-0.016	-0.022	3.6579	0.454
5	-0.149	-0.108	5.5678	0.351
6	-0.030	-0.041	5.6475	0.464
7	-0.044	-0.013	5.8189	0.561
8	-0.118	-0.155	7.0797	0.528
9	0.095	0.107	7.9054	0.544
10	0.059	0.062	8.2303	0.606
11	-0.025	-0.118	8.2908	0.687
12	-0.149	-0.152	10.417	0.579
13	0.078	0.106	10.999	0.611
14	-0.141	-0.126	12.959	0.530
15	-0.079	-0.152	13.586	0.557
16	-0.041	0.001	13.758	0.617
17	0.019	0.005	13.794	0.682
18	-0.028	-0.060	13.877	0.737
19	-0.004	-0.111	13.879	0.791
20	-0.062	-0.127	14.302	0.815
21	-0.126	-0.093	16.050	0.767
22	-0.061	-0.129	16.467	0.792
23	0.112	0.046	17.890	0.763
24	0.092	0.078	18.871	0.759
25	-0.007	-0.105	18.878	0.803
26	0.157	0.054	21.840	0.697
27	0.016	-0.006	21.871	0.744
28	0.015	-0.062	21.898	0.786
29	-0.001	-0.002	21.898	0.824
30	-0.086	-0.135	22.863	0.821
31	-0.001	0.076	22.863	0.854
32	-0.017	-0.022	22.903	0.881

Source: Author's calculations.

Figure 4. The correlogram of the standardized residuals and the squared standardized residuals.

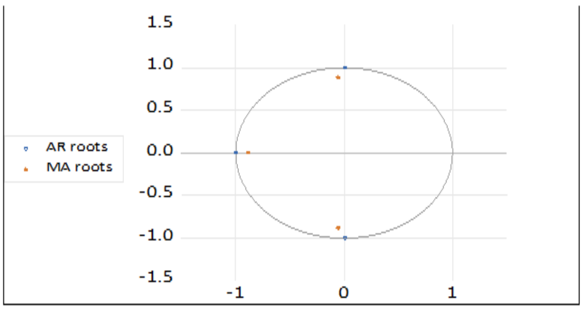


Source: Authors' calculations.

Figure 5. Residual Diagnostics/Histogram–Normality Test.

Furthermore, the model stability is proven by plotting out the inverse roots of AR and MA characteristic polynomials, as the corresponding inverse roots are in the unit circle (Figure (6)).

As the model is stable and reliable, the quarterly GDP values from 2021/22 to 2025/26 were predicted using a dynamic forecast (Table (4)). Figures (7) and (8) depict the trend of actual and forecasted values within 95 percent confidence intervals.



Source: Author's calculations.

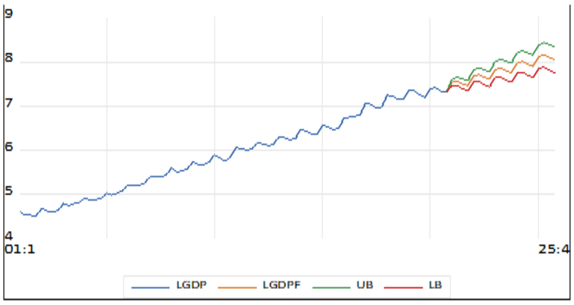
Figure 6. Inverse Roots of AR and MA.

The forecasted values indicate that Egyptian GDP will witness a continuous increase, provided that no severe fluctuations encounter the economy throughout the forecast period.

Table 4. Forecasted values of Egyptian GDP

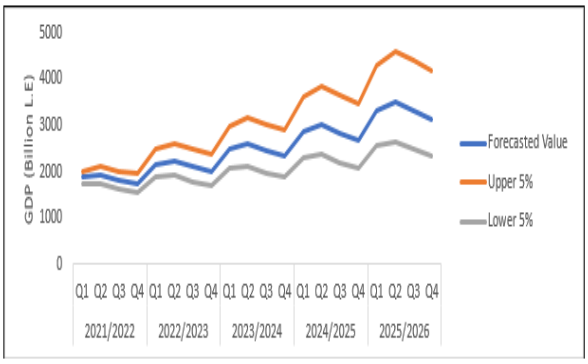
Year	Quarter	Forecasted Value (Billion L.E.)	Confidence intervals (5%)	
			Upper	Lower
2021/22	Q1	1876.359	2001.662	1758.9
	Q2	1926.53	2116.684	1753.459
	Q3	1805.043	2016.216	1615.988
	Q4	1742.719	1961.094	1548.66
2022/23	Q1	2163.301	2477.078	1889.27
	Q2	2236.21	2608.690	1916.914
	Q3	2099.907	2480.900	1777.423
	Q4	2015.358	2391.509	1698.37
2023/24	Q1	2493.989	2997.841	2074.821
	Q2	2595.077	3169.358	2124.854
	Q3	2443.063	3019.769	1976.495
	Q4	2331.175	2889.158	1880.955
2024/25	Q1	2875.106	3601.372	2295.301
	Q2	3010.847	3826.958	2368.775
	Q3	2842.411	3657.597	2208.91
	Q4	2697.089	3475.136	2093.24
2025/26	Q1	3314.358	4309.626	2548.937
	Q2	3492.432	4604.405	2649.003
	Q3	3307.134	4417.428	2475.906
	Q4	3121.143	4169.533	2336.361

Source: Author's calculations.



Source: Author's calculations.

Figure 7. Forecasted values of Egyptian GDP.



Source: Author's calculations.

Figure 8. Forecasted quarterly values of Egyptian GDP.

CONCLUSION

ARIMA (3,1,3) is calibrated to forecast Egypt's GDP quarterly time series for the fiscal years (2021/22-2025/26) using the Box-Jenkins approach. As a result, it is expected that the Egyptian GDP will keep rising within the upcoming five years as long as severe fluctuations are not encountered. These findings help public and private sector decision-makers grasp the quarterly GDP pattern better when directing future planning and development. No work has been published on the ARIMA model calibrated with quarterly data in the Egyptian setting. However, the study's most significant flaw is the lack of data. Future studies might create the Autoregressive Conditionally Heteroscedastic (ARCH) model and the Generalized Autoregressive Conditional Heteroskedasticity (GARCH) model to account for variance analysis as well as macroeconomic models employing Vector Error Correction Models (VECM) and Vector Autoregression (VAR) to understand economic dynamics.

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نمذجة وتوقع الناتج المحلي الإجمالي المصري: نموذج الانحدار الذاتي والمتوسطات المتحركة المتكاملة

فيكتور شاكر

قسم الاقتصاد الزراعي ـ كلية الزراعة- جامعة القاهرة ــ مصر

الملخص

الناتج المحلي الإجمالي (GDP) هو القيمة الإجمالية لجميع ما تم انتاجه من سلع وخدمات داخل النطاق الجغرافي لدولة ما، وهو يعد بمثابة أفضل مؤشر للنمو الاقتصادي. من ناحية أخرى، يرتبط نصيب الفرد من الناتج المحلي الإجمالي ارتباطًا وثيقًا بمستوى المعيشة عبر الزمن. في هذا الإطار، تهدف الدراسة الحالية إلى تحليل الناتج المحلى الإجمالي والتنبؤ بقيمته خلال الخمس سنوات التالية على أساس ربع سنوي؛ بغية مساعدة متخذي القرار في التوجيه المستقبلي للتخطيط والتنمية. ولتحقيق الهدف البحثي؛ تم الاعتماد على البيانات الربع سنوية المنشورة من قِبل وزارة التخطيط والتنمية الاقتصادية خلال للفترة (2021/2020-2002/2001) وتطبيق منهجية الانحدار الذاتي والمتوسطات المتحركة المتكاملة Autoregressive Integrated Moving Average (ARIMA) (p,d,q)، التي تجمع بين أسلوبي الانحدار الذاتي والمتوسط المتحرك، والمعروفة باسم بوكس – جينكيز (Box-Jenkines). وتعتمد هذه المنهجية على مراحل متسلسلة هي: التشخيص (Identification)، والتقدير (Estimation)، والفحص والتدقيق (Diagnosis and Checking) والتنبؤ (Forecasting).وفقاً لذلك، أشارت النتائج إلى أن نموذج (3,1,3) ARIMA يعد أفضل نموذج للتحليل والتنبؤ في ضوء البيانات المتاحة والاختبارات القبلية والبعدية. بناءً على ذلك، من المتوقع أن تستمر قيمة الناتج المحلى الإجمالي في الارتفاع مالم تحدث تقلبات سياسية أو اقتصادية أو اجتماعية حادة. وبالرغم من أن الدراسة الحالية تسهم في سد الفجوة البحثية في الدراسات السابقة والتي اقتصرت على تحليل السلاسل السنوية؛ إلا أن قصر طول السلسلة الزمنية يعد من أهم المحددات. وفيما يتعلق بالدراسات المستقبلية، تقترح الدراسة ضرورة تطبيق نماذج الانحدار الذاتي المشروط بعدم التباين (ARCH&GARCH) إلى جانب النماذج الاقتصادية الكلية مثل نموذج متجه الانحدار الذاتي (VAR) ونموذج متجه تصحيح الخطأ (VECM).

الكلمات الدالة: الناتج المحلى الإجمالي، سلسلة ربع سنوية، منهجية بوكس - جينكيز، نموذج الانحدار الذاتي والمتوسطات المتحركة المتكاملة، الاقتصاد المصري