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Application of the ARIMAX Model in Forecasting the Population Growth Rate of Congo B

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Abstract: Population forecasting models play an important role in analyzing current population processes and predicting their future development. The Republic of the Congo saw population growth from 1.02 million to 5.66 million people between 1960 and 2021. This is an increase of 455.6% over 61 years. Urbanization is a trend that is accelerating and growing at a 3.2% yearly rate with the country's current economic situation, which is not ideal. The objective of this study is to show and forecast the population growth rate in Congo B using the ARIMAX system. Based on the data of per capita GDP and population growth rate in Congo B from 1982 to 2019, this paper uses per capita GDP as the input variable and population growth rate as the response variable and uses the ARIMAX model for research. The predictions for Congo B's population growth rate in 2020-2024 were correct. The results were 11.77‰, 11.60‰, 11.55‰, 11.34‰, 11.03‰, respectively. This indicates a country with a lower population growth rate. The results of this work allow the government and Congolese leaders to use them as a reference when creating a baseline and responsible growth strategy because they show that the rate of population expansion in Congo B will slow over the next five years and that migration will remain moderate.

Keywords: Population Growth Rate, Per Capita GDP, Arimax Model, SAS Software

1. Introduction

Population is related to the destiny of a country and is the foundation of national development. Since it affects the supply of welfare and development, the problem of population expansion is essentially not one of numbers but one of human welfare. As is common knowledge, the population of a substantial impact on the political, economic, and social growth of the nation, likewise directly tied to the size and makeup of the population is the study of social issues. GDP is an important indicator to measure a country's wealth and economic strength. GDP is part of the National income The Republic of the Congo saw a population growth from 1.02 million to 5.66 million people between 1960 and 2021. This is an increase of 455.6% over 61 years. The year 2007 in the Congo saw the largest increase, at 3.50%. The 1961 gain was the smallest at 2.44%. The population of the entire planet expanded by 158.5 percent during the same time span. From 2012 to 2020, the average age in the Congo increased by 0.69 years, from 18.81 to 19.50 years (median value). The major cities in the country are home to about 68% of the population. Urbanization is a trend that is accelerating and growing at a 3.2% yearly rate. The objective of this study is to show and forecast the population growth rate in Congo B using the application of the ARIMAX system.

2. Literature Review

In recent years, many scholars at home and abroad have done a lot of research work on the prediction and analysis of population data. Based on the revised population data for 2006–2015, He et al. predicted the population by establishing a time series model and a two-layer "small world [1]" model and obtained the total population from 2017 to 2030. They also used data envelopment analysis to discuss the impact of China's population on economic development. In reference, two kinds of population prediction models were established by using the ARIMA model based on population time series and the exponential smoothing method, and the optimal models were also obtained. This model was used to estimate the population of China from 2006 to 2015.

According to Google Scholars, David Shapiro et al. conducted research on “fertility in the Democratic Republic of the Congo and concluded that the total fertility rate in Congo [2]” is as high as 6.7 and that a strong case can be made for fertility being significantly lower. By using the Arimax model to analyze the population data of Zhejiang Province from 1978 to 2016, Jie Dai and Shuping Chen concentrate their research on “the use of the ARIMA model in forecasting population data [3]”. The results of the experiments demonstrate that the model's actual fitting effect is good. An acceptable ARIMAX model is suggested by Christogonus Ifeanyichukwu Ugoh and colleagues “to forecast Nigeria's GDP [4]”. The World Bank provided the data for the study, which covered the years 1990 through 2019. Based on the prediction accuracy measurements, the results demonstrated that the ARIMAX (0, 1, 1) is more optimal and sufficient for projecting Nigeria's GDP. C. Guarnaccia et al. based their research on “on the use of Arima model to predict urban sound pressure level [5]” where the case study of the city of Messina (South Italy) was presented, revealing meaningful prediction findings of the TSA models, both with a deterministic and a stochastic approach. The deterministic decomposition provided extremely strong results on average, but with the option to extend the prediction to any time in the future, whereas the ARIMA models demonstrated the best outcomes across a narrow time range. The appropriate technique can be chosen and used on the data under study depending on the application required in each individual scenario. Nyoni, Thabani, et al. use “the Box-Jenkins ARIMA technique to model and forecast Togo's total population [6]” over the next three decades using annual time series data from 1960 to 2017. Diagnostic tests like the ADF tests reveal that the annual total population of Togo is neither I (1) nor I (2), but for the researcher's convenience, he or she has assumed that it is I (2). According to the study, the ARIMA (3, 2, and 0) model is the best model based on the AIC. Additionally, the diagnostic tests show that the proposed model is stable. The study's findings indicate that Togo's population would grow overall during the following three decades, reaching a high of 14.2 million people in 2050. The Togo government has been given three policy recommendations to take into consideration in order to capitalize on an increase in the country's overall population. Tu et al. used “the ARIMA seasonal product model to forecast and analyze Guilin tourism demand by varying the number of tourists in Guilin [7]”, as well as run diagnostic tests on the model. It was found that the product-season model has a good fitting effect on the number of tourists in Guilin. Yuniar Farida et al. use “Madiun Regency annual population… [8]” data between 1983 and 2021 to generate an ARIMA forecasting model (0, 2, 1) with a MAPE value of 8.42%. The analysis also revealed that a rise of 17947 persons, or 2.39%, is expected between 2022 and 2024. The findings of this study are anticipated to be used by the Madiun Regency government as information to foresee the emergence of issues brought on by the region's population level in the future. Eralda DHAMO et al use “Box Jenkins' ARIMA approach… [9]” to examine the number of births per month in Albania from 1985 to 2008. To take process seasonality into account, they employed the Box-Jenkins approach and the R programming language. To predict the number of births in Albania in the future, they model data using an ARIMA (p, d, q) stochastic process. For governmental or nongovernmental organizations, insurance firms, and anybody else interested in the evolution of birth rates in Albania, the model may be helpful. Muhammad Zakria et al. “modeled Pakistan's population [10]” from 1951 to 2007. According to the findings, if the current growth rate trend continues, Pakistan's population would increase to 230.68 million in 2027. Some academics have noted a negative link between population growth rate and per capita GDP. This supports the prediction that the ARIMAX model, which uses the population growth rate (BR) as the response variable and the per capita GDP (PGDP) as the input variable, will accurately estimate the rate at which the population of Congo B will grow.

3. Materials and Methods

3.1. The Dynamic Regression Models

Dynamic regression avoids this by explicitly allowing temporal variability of regression coefficients and leaving part of the system properties that change over time. Also, use unobservable state variables allows direct modeling of the processes driving the observed variability, such as seasonal changes or external forcing, we might explicitly allow some modeling error Yi Danhui, Wang Yan. “Applied Time Series Analysis [11]”.

3.2. Regression Models

Dynamic regression model namely ARIMAX model. The structure of the model ideas:

Let output variables $\{y_t\}$ and k input variables $\{x_{1t}\}$, $\{x_{2t}\}$,..., $\{x_{kt}\}$ are stable, then Xiao DH, Xie QM, Yang WD, established on “Application of Integrated Forecasting Model Based on Multi-variables in Tunnel Vault Settlement [12]”

$$Y_t = \beta_0 + \sum_{i=1}^{k} \frac{\Theta_i(B)}{\Phi_i(B)} B^{li} X_{it} + \varepsilon_t \qquad (1)$$
$$\varepsilon_t = \frac{\Theta(B)}{\Phi(B)}\, a_t$$

Among them, β_0 is the constant; $\{a_t\}$ is a pure random sequence; $\{\varepsilon_t\}$ is the residual sequence;

$\Theta_i(B) = \theta_{i0} + \theta_{i1}B + \theta_{i2}B^2 - \cdots - \theta i_{qi}B^{qi}$, $1 \le \mathrm{i} \le k$ for $\{X_{it}\}$ p_i order moving average coefficients of polynomial;

$\Phi_i(B) = 1 - \phi_{i1}B - \phi_{i2}B^2 - \cdots - \phi_{ip_i}B^{p_i}$, $1 \le \mathrm{i} \le k$ for $\{X_{it}\}$ p_i order autoregressive coefficients of polynomial;

$$\Theta(B) = 1 - \theta_1 B - \theta_2 B^2 - \cdots - \theta_q B^q$$

The moving average coefficient polynomial of $\{\varepsilon_t\}$; $\Phi(B) = 1 - \phi_1 B - \phi_2 B^2 - \cdots - \phi_p B^p$, The self -regression coefficient polynomial of $\{\varepsilon_t\}$.

4. Congo's B Population Growth Rate Sequence Prediction

4.1. Select Observation Value

Select the Total population and GDP growth data from 1982 to 2019 from Congo statistics yearbook (2021), as an observation value to predict the Congo's B Population Growth rate. See Table 1.

4.2 Sample Data

Table 1. *1982 and 2019 – Congo B total population and GDP growth.*

year	Total population	GDP growth (annual %)
1982	1884873	23.5976999601492
1983	1940454	5.85396283993704
1984	1996994	6.9761310544814
1985	2054308	-1.18566085432533
1986	2112359	-6.86152643665193
1987	2171319	0.189376640368906
1988	2231462	1.76626342847234
1989	2293161	2.59987651814491
1990	2356740	1.00000356627487
1991	2422312	2.39536745255616
1992	2489945	2.61194805533871
1993	2559880	-0.979683208744774
1994	2632345	-5.49307574541402
1995	2707532	3.9853243781107
1996	2785815	4.29048155870402
1997	2867283	-0.624812152260716
1998	2951651	3.73755276980884
1999	3038432	-2.58219935813743
2000	3127420	7.5759803952642
2001	3217930	3.80260189913561
2002	3310376	4.58187006108889
2003	3406915	0.813264076303781
2004	3510468	3.47663162118089
2005	3622775	7.75575897806648
2006	3745143	7.98623836334291
2007	3876123	-6.61399480441001
2008	4011487	6.30637595585259
2009	4145400	11.6372888615758
2010	4273738	9.93126543095578
2011	4394842	2.20591936286718
2012	4510197	9.94715314257564
2013	4622757	-0.712434451876447
2014	4736965	6.71667933378647
2015	4856093	-3.55058176545468
2016	4980996	-10.7832382689225
2017	5110701	-4.38253094629233
2018	5244363	-4.80535155756866
2019	5380504	-0.0868859578877448

5. Establish a Dynamic Regression Model

5.1. Test the Stability of $\{l_nPGDP\}$ and $\{l_nBR\}$, and $\{\nabla l_nPGDP\}$ and $\{\nabla l_nBR\}$

In order to make the data meet the homogeneity of variance, the two variables take logarithm, get $\{l_nPGDP\}$ and $\{l_nBR\}$. Take the first -order difference between $\{l_nPGDP\}$ and $\{l_nBR\}$, and get $\{\nabla l_nPGDP\}$ and $\{\nabla l_nBR\}$.

5.2. Draw the Timing Diagram of $\{l_nPGDP\}$ and $\{l_nBR\}$ and $\{\nabla l_nPGDP\}$ and $\{\nabla l_nBR\}$.

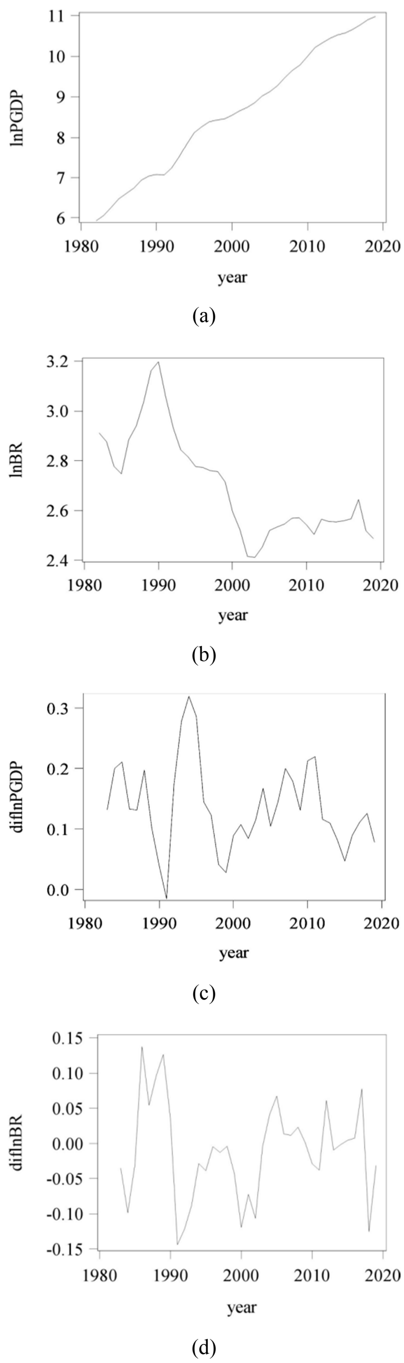


Figure 1. *$\{l_nPGDP\}$ and $\{l_nBR\}$ and $\{\nabla l_nPGDP\}$ and $\{\nabla l_nBR\}$ the sequence diagram.*

From figure 1 (a), (b) it can be seen that $\{l_nPGDP\}$ upward trend, there is a downturn in the $\{l_nBR\}$ shows both are not stable. From Figure 1 (c), (d), it can be seen that $\{\nabla l_nPGDP\}$ and $\{\nabla l_nBR\}$ do not have a trend. Wang YL, Wang Xi. established on "Prediction of the trend of birth rate in Fenghua district of Ningbo city by autoregressive moving average model It can be considered that $\{\nabla l_nPGDP\}$ and $\{\nabla l_nBR\}$ are stable [13]". The ADF test is performed to accurately test the stability of $\{\nabla l_nPGDP\}$ and $\{\nabla l_nBR\}$.

The program used by SAS software is

```
proc arima data=a;
identify var=lnPGDP(1) stationarity=(adf=2);
identify var=lnBR(1) stationarity=(adf=2); run;
```

6. Results and Discussion

The analysis results are shown in table 2 and table 3.

Table 2. *$\{\nabla l_n PGDP\}$ ADF test results.*

type	Delay in order	τ statistics	P value
	0	−3.366 8	0.201 1
	1	−5.309 1	0.105 3
Zero average	2	−3.429 9	0.196 4
	0	−14.264 2	0.030 6
	1	−33.135 6	0.000 2
Single average	2	−38.453 4	0.000 2
	0	−14.974 0	0.126 6
	1	−34.973 2	0.000 1
Trend	2	−42.248 0	<0.000 1

Table 3. *$\{\nabla l_n BR\}$ ADF test results.*

type	Delay in order	τ statistics	P value
	0	−19.932 0	0.000 7
	1	−25.766 8	<0.000 1
Zero average	2	−38.708 4	<0.000 1
	0	−20.427 5	0.004 0
	1	−26.346 8	0.000 4
Single average	2	−41.519 1	0.000 2
	0	−20.416 0	0.029 1
	1	−25.865 3	0.004 8
Trend	2	−41.099 8	<0.000 1

From table 2, $\{\nabla l_n PGDP\}$ is smooth. From table 3, rejected the original hypothesis that $\{\nabla l_n BR\}$

6.1. The $\{\nabla l_n PGDP\}$ Autoregressive Moving Average Model Is Set up

For $\{\nabla l_n PGDP\}$ ARMA model, carries on the parameter estimation and the pure random inspection of the residuals. The program used by SAS software is

```
proc arima data=a;
identify var=lnPGDP(1);
ESTIMATE P=1 NOCONSTANT;
RUN;
```

The results are shown in table 4 and table 5.

Table 4. *$\{\nabla l_n PGDP\}$ ARMA model parameter estimation.*

parameter	The estimate	τ statistics	P value
ϕ	0.906 4	12.63	12.63

Table 5. *Residual white noise test results.*

Delay in order	LB statistic	P value
6	5.59	0.348 7
12	12.02	0.362 1
18	14.86	0.605 2

It can be concluded from Table 4 that the model established by $\{\nabla l_n PGDP\}$ is AR (1), the parameter is significantly not 0, and the model structure is the structure of.

$$\nabla l_n PGDP = \frac{\varepsilon_{1l}}{1-0.9064B} \tag{2}$$

From Table 5, According to Kahlil M, Kahlil M, Kahlil M, et al. on "Birth Rate Prediction in China when the significant level is 0.05 [14]", the residual $\{\varepsilon_{1t}\}$ is white noise. After the pre -whitening noise treatment, the same model is established for $\{\nabla l_n BR\}$ to get:

$$\nabla l_n BR = \frac{\varepsilon_{1l}}{1-0.9064B} \tag{3}$$

6.2. Dynamic Regression Model Is Established

Examine the amount of interoperability between $\{\nabla l_n PGDP\}$ and $\{\nabla l_n BR\}$, and draw the number of interoperability relationships, as shown in Figure 2, establish the Arimax model.

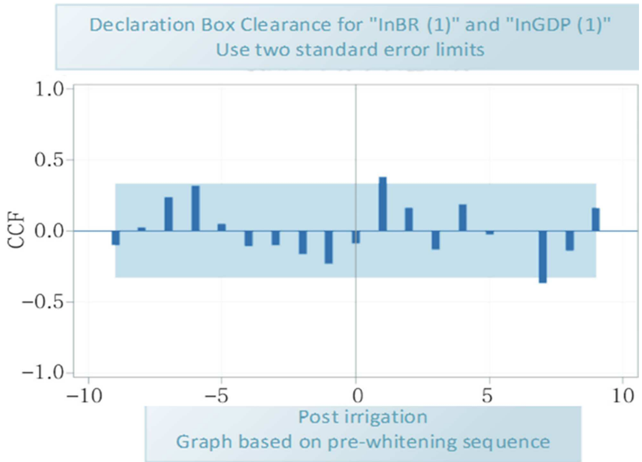


Figure 2. *$\{\nabla l_n PGDP\}$ and $\{\nabla l_n BR\}$, represent the relationship between each other.*

As can be seen from Figure 2, the input sequence and the response sequence have 1st and 7th order delay effects if the number of correlations is significantly non-zero at 1st and 7th order delays Ren Dong, et al. on 'Factors Affecting Birth Rate and Policy Options [15]. According to the relationship in the figure, through experiments, the ARIMAX model structure is obtained.

$$l_n BR = \omega_1 l_n PGDP_{t-1} + \omega_2 l_n PGDP_{t-7} + \frac{a_t}{1-B^0} \tag{4}$$

Model parameter estimation results as shown in table 6, the diameter of the model is obtained by table 6:

$$l_n BR = 0.17955\, l_n PGDP_{t-1} - 0.32951 l_n PGDP_{t-7} + \frac{a_t}{1-B^0} \tag{5}$$

Table 6. *ARIMAX model parameter estimation results.*

parameter	The estimate	τ statistics	P value
ω_1	0.179 55	2.20	0.036 6
ω_2	−0.329 51	−4.36	0.000 2

From Table 7, it can be seen that the residual of model $\{a_t\}$ is white noise, indicating that the model is co-organized Zhu Qian. Fertility Rate and Economic Development in China [16]. It can be seen from Table 8 and Table 9 that $\{a_t\}$ and input sequences $\{l_n PGDP_{t-1}\}$ and $l_n PGDP_{t-7}$ are both

0, indicating that the model is effective. The program is a specific SAS software:

```
proc arima data=a;
identify var=lnPGDP(1);
estimate P=1 NOCONSTANT;
identify var=lnBR(1) crosscorr=lnPGDP(1);
estimate input= (1$lnPGDP,7$lnPGDP) noconstant;
forecast lead=5 id=year interval=year out=result;
run;
```

Table 7. *Residual $\{a_t\}$ white noise test results.*

Delay in order	LB statistic	P value
6	5.51	0.480 5
12	7.10	0.850 7
18	10.01	0.931 6

Table 8. *$\{a_t\}$ and $\{l_nPGDP_{t-1}\}$ the cross-correlation of inspection results.*

Delay in order	Statistical statistics	P value
6	1.30	0.934 6
12	5.01	0.930 6
18	8.15	0.963 2

Table 9. *$\{a_t\}$ and $\{l_nPGDP_{t-7}\}$ the cross-correlation of inspection results.*

Delay in order	Statistical statistics	P value
6	4.29	0.509 1
12	7.92	0.720 8
18	14.73	0.615 2

6.3. Dynamic Regression Model Prediction

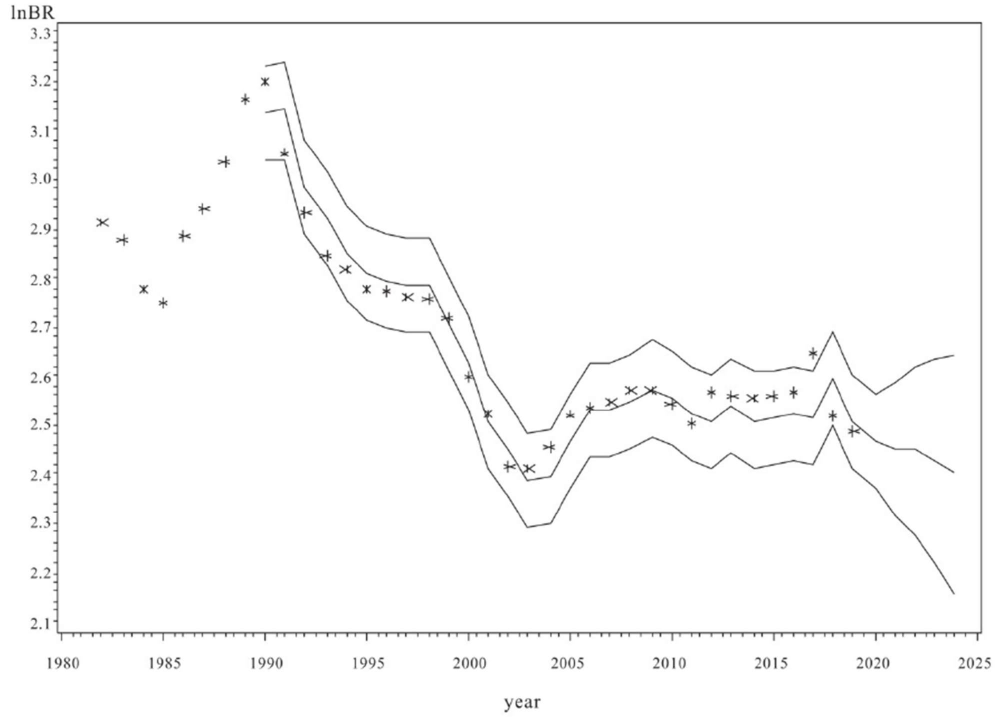
Table 10. *Congo B after the population growth rate of prediction results.*

year	Life expectancy at birth, total (years)	Population aged 15 to 64 years (% of the total population)	Population ages 65 and above, total
1990	54.638	52.4548984464537	68708
1991	54.281	52.7272164322825	70424
1992	53.867	53.0418658672938	72010
1993	53.424	53.3783902560791	73472
1994	52.984	53.7087653783983	74833
1995	52.583	54.0174704907080	76101
1996	52.252	54.2615253732308	78121
1997	52.016	54.4924806785525	79994
1998	51.899	54.7095231916283	81738
1999	51.925	54.9183740434625	83358
2000	52.123	55.1208011994586	84862
2001	52.517	55.1981660276954	87085
2002	53.091	55.2941091177557	89151
2003	53.817	55.3927562767800	91119
2004	54.667	55.4745407165085	93050
2005	55.600	55.5291178723492	94968
2006	56.573	55.6031935780255	97690
2007	57.541	55.6577597333828	100399
2008	58.466	55.7011790643168	103040
2009	59.321	55.7571770672537	105524
2010	60.093	55.8424945322951	107818
2011	60.785	55.6174917699013	111365
2012	61.423	55.4567104467009	114701
2013	62.022	55.3526657872501	117946
2014	62.022	55.2936936982581	121252
2015	63.097	55.2762868106987	124749
2016	63.556	55.3186952970851	129788
2017	63.954	55.4126395725043	135084
2018	64.290	55.5547780005145	140639
2019	64.570	55.7413352047799	146426

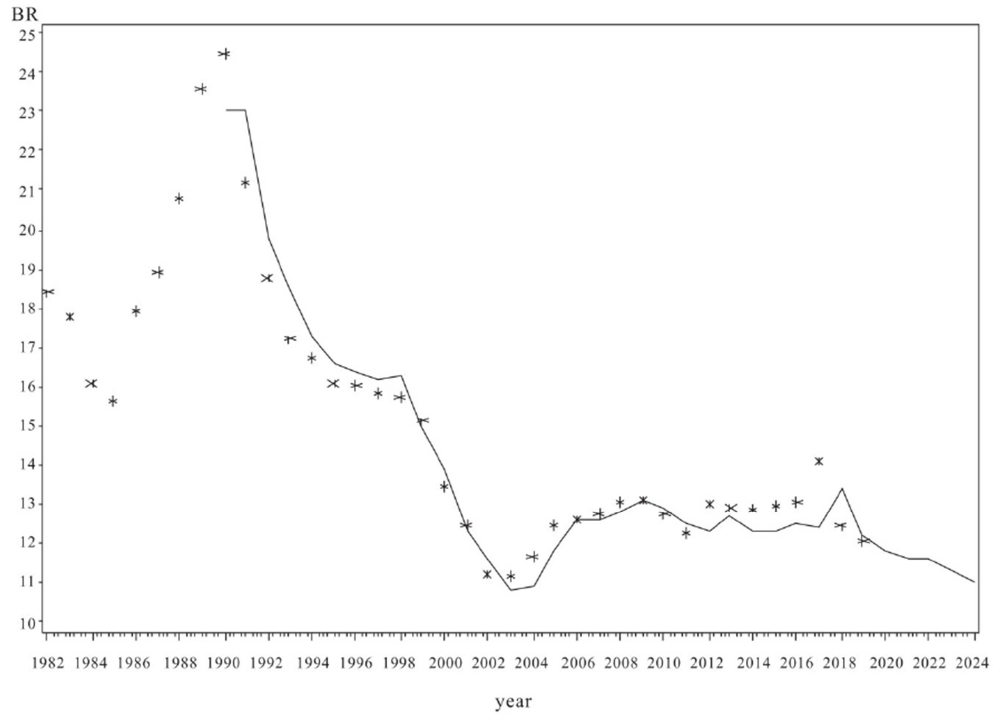
According to Table 10, the absolute value of the relative error obtained by fitting the ARIMAX model to predict Congo B's population growth rate from 1990 to 2019 is less than 12.3%, and the MAPE (mean absolute percentage error) is 3.83%. Prediction accuracy is typically thought to be less than 10% of the curve. GUAN Heshan, ZOU Pure Brightness, LUO Zhi-chao. “Classification and identification of stationary time series [17]”, indicating that the model fits well. The Congo's population growth rate will be 2465.21, 2450.96, 2446.98, 2427.93, and 2400.71, correspondingly, in the following five years, from 2020 to 2024, according to this model. After that, indexing, the birth rate will be 11.77, 11.60, 11.55, 11.34, and 11.03, correspondingly, from 2020 to 2024.

6.4. Graphic Fitting

Draw $\{l_n BR\}$ and $\{BR\}$ fitting diagram, as shown in figure 3 (a), (b). Figure 3 (a) $\{l_n BR\}$ fitting figure; for the birth rate figure 3 (b) $\{BR\}$ fitting curve, visible fitting effect is good Wang Yuanzheng, Xu Yajing on "Application of ARIMAX Model for Multivariate Stationary Time Series [18]".



(a)



(b)

Figure 3. *$\{l_n BR\}$ and $\{BR\}$ fitting.*

7. Conclusion

Many factors affect changes in the population growth rate. An ARIMAX model is developed with the province's per capita GDP as the input sequence and the population growth rate response sequence in order to take the effect of per capita GDP on population growth rate into account Chen Yan. Use examined on “ARIMAX Model Approach: Disposable Income and Consumption Expenditure of Chongqing Urban Residents [19]”. Congo B population growth rate series data from 1982 to 2019 show that the model's anticipated MAPE value of 3.83%, which was the actual value after the event, was accurate.

The predicted findings can be utilized as a reference when creating a responsible growth strategy because they show that Congo B's population expansion rate will slow down during the following five years and that migration will stay moderate.

Appendix

```
Data a;
input BR PGDP;
year=intnx('year','01jan1982'd,_n_-1);
lnPGDP=log(PGDP);
lnBR=log(BR);
format year year4.;
cards;
1884873
1940454
1996994
2054308
2112359
2171319
2231462
2293161
2356740
2422312
2489945
2559880
2632345
2707532
2785815
2867283
2951651
3038432
3127420
3217930
3310376
3406915
3510468
3622775
3745143
3876123
4011487
4145400
4273738
4394842
4510197
4622757
4736965
4856093
4980996
5110701
5244363
5380504
;
RUN;
proc arima data=a;
identify var=lnPGDP(1) stationarity=(adf=2);
identify var=lnBR(1) stationarity=(adf=2);
run;
proc gplot data=a;
plot lnPGDP*year=1 lnBR*year=2 /overlay;
symbol1 c=red i=join v=none w=2 l=2;
symbol2 c=black i=join v=none w=2 l=2;
run;
proc arima data=a;
identify var=lnPGDP(1);
ESTIMATE P=1 NOCONSTANT;
RUN;
proc arima data=a;
identify var=lnPGDP(1);
estimate P=1 NOCONSTANT;
identify var=lnBR(1) crosscorr=lnPGDP(1);
estimate input=(1$lnPGDP,7$lnPGDP) noconstant;
forecast lead=5 id=year interval=year out=result;
run;
proc gplot data=result;
plot lnBR*year=1 forecast*year=2 l95*year=3
u95*year=3/overlay;
symbol1 c=black i=none v=star;
symbol2 c=red i=join v=none;
symbol3 c=green i=join v=none;
run;
data out;
set result;
BR=exp(lnBR);
FORECAST=EXP(FORECAST);
l95=exp(l95);
u95=exp(u95);
run;
proc gplot data=out;
plot BR*year=1 forecast*year=2 /overlay;
symbol1 c=black i=none v=star;
symbol2 c=red i=join v=none; run;
```

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