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Time Series Modeling of Livebirths and Stillbirths: A Case Study of Obafemi Awolowo University Teaching Hospital Complex, Ile-Ife

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Abstract: *Livebirths and stillbirths are key public health indicators, with significant social and economic consequences. This study applies time series modeling to the quarterly data of livebirths and stillbirths recorded at Obafemi Awolowo University Teaching Hospital Complex (OAUTHC), Ile-Ife, spanning from 2001 to 2020. Using Augmented Dickey-Fuller tests, the data were confirmed to be stationary. Appropriate ARMA models ARMA(2,3) for livebirths and ARMA(1,3) for stillbirths were fitted based on minimum values of AIC, BIC, and HQIC. Forecasts show that livebirths are expected to fluctuate before stabilizing, while stillbirths are projected to remain relatively constants at around 30 cases per quarter. though with wide confidence intervals early in the forecast. However, the relatively low R2 values, especially for stillbirths, suggest that other unmeasured factors such as healthcare access, socio-economic conditions, or maternal risk factors may be influential. These findings underscore the importance of continuous improvement in maternal healthcare, data-driven planning and timely intervention.*

Keywords: *Livebirths, Stillbirths, ARMA models, Time Series, Forecasting, Nigeria, Hospital Records*

INTRODUCTION

Childbirth serves as a vital measures in global public health assessment, resulting in either livebirths and stillbirths, each with significant implications for the healthcare system. In Nigeria, the burden of stillbirths remains alarmingly high despite improvements in maternal health services. With recent estimates indicating over 40 stillbirths per 1000 births, there is a pressing need for the data driven methods to understand and address this issue. This study analyzes a 20 year trend of livebirths and stillbirths using time series modelling, aiming to generate accurate forecasts and support evidence based policy decisions at OAUTHC, Ile-Ife.

Understanding livebirths and stillbirths is fundamental to advancing maternal and infant health. According to the World Health Organization (WHO, 2015), a livebirth is the complete expulsion or extraction from its mother of a product of conception, irrespective of the duration of pregnancy, which, after such separation, breathes or shows any other evidence of life, such as beating of the heart, pulsation of the umbilical cord, or any definite movement of voluntary muscles, whether or not the umbilical cord has been cut or the placenta is attached. This definition is critical for public health reporting and statistical analysis.

Stillbirth, on the other hand, is characterized by the absence of any signs of life following delivery. WHO, (2021) states that a stillbirth occurs when the fetus shows no signs of life after being fully delivered. In 2015, Nigeria was identified as having the second highest stillbirth rate globally, with estimated 317,700 stillbirths accounted for 12.2% of the 2.6 million estimated global stillbirths (Blencowe, et al., 2016, Okonofua, 2019). This suggests that Nigeria still makes substantial contribution to the global burden of stillbirths.

According to WHO estimates, approximately 2.4 million stillbirths occur annually, with the vast majority recorded in low and middle income nation (Lawn et al, 2016). Despite global progress in reducing child mortality, declines in stillbirth rate have been slower. The highest burden in Sub-Saharan Africa and South Asia, often resulting from preventable conditions such as maternal infections hypertensive disorders and complications during labor. These outcomes are further exacerbated by inadequate access to skilled birth attendants, delayed initiation of antenatal care and insufficient obstetric services further exacerbate these outcomes. Livebirths though influenced by similar factors, tends to respond more positively to improvements in healthcare services (Lawn et al., 2016; Hug et al., 2021; WHO, 2022). Research highlights that early antenatal care, maternal education, and access to emergency obstetric services are essential for improving childbirth outcomes. Factors such as higher parity, advanced maternal age, preeclampsia, diabetes, anemia increase the risk of stillbirth. Additionally, institutional deliveries and health system improvement strategies like the implementation of partographs and maternal death audits contribute to improved livebirth rates and a reduced stillbirths (Kibret et al., 2023; Aminu et al., 2014; Chuwa et al., 2017; Lawn et al., 2016). Persistent challenges and such as cultural beliefs, stigma and inadequate data reporting hinder progress in addressing stillbirths, Stillbirths are often underreported or misclassified, unlike neonatal deaths, leading to gaps in healthcare planning

(Lawn et al., 2016; Blencowe et al., 2020). Enhancing surveillance systems and adopting standardized definitions and reporting mechanism are essential for accurate tracking and effective interventions. Efforts to lower stillbirth rates must be embedded within comprehensive maternal and newborn health strategies. Addressing socioeconomic factors such as poverty, gender inequality and lack of education and gender inequality is also a fundamental (Bhutta et al., 2014; Lawn et al., 2016). In addition, policy changes that allocate more resources to maternal health and support community based initiatives can substantially improve childbirth outcomes (Tuncalp et al., 2015; WHO, 2020).

Several factors influence the likelihood of livebirth, such as maternal age, level of education, income, and access to healthcare services. Research indicates that younger women and those from more privileged backgrounds are more likely to experience livebirths (Mathews & Hamilton, 2016). Access to timely and adequate prenatal care plays a crucial vital role in ensuring healthy childbirth outcomes (Katz et al., 2015). In contrast, stillbirths are linked with several maternal and fetal risk, such as hypertension and diabetes, harmful behaviors such as smoking, and alcohol use, and fetal anomalies. Poor maternal nutrition and inadequate antenatal care have also been identified as major contributors (McClure et al., 2016). Beyond the medical implications, stillbirths can lead to long term psychological trauma for families and economic burdens. Support systems, including grief counseling, are therefore vital (Cacclatore et al., 2013). Additionally, stillbirths contribute to increased healthcare expenditures and productivity losses at the societal level.

Reducing stillbirth rates requires a combination of interventions, such as improving prenatal care, raising awareness about risk factors, and expanding maternal health education. The WHO's Every Newborn Action Plan calls for integrated approaches that tackle both medical and social contributors to the poor birth outcomes (WHO, 2014). Although progress has been made in boasting livebirth rates, stillbirth remains a major global health burden. By identifying and addressing the underlying causes through targeted health programs and policies, significant improvements in maternal and neonatal well being can be achieved. Previous studies have identified multiple maternal, fetal, and environmental risk factors contributing to stillbirths

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(Odendaal et al., 2021; Malacova et al., 2018). Moreover, the World Health Organization emphasizes the use of accurate and complete data in evaluating maternal health interventions.

In recent years, there has been growing interest in using timeseries modelling and spatial analysis to understand trends in livebirths and stillbirths. These approaches allow researchers to predict future patterns and identify high risk areas requiring targeted interventions (Gebremedhin et al., 2021; Liu et al., 2020). Additionally, there has been a shift in global health discourse towards including stillbirths in the broader maternal and child health agenda, particularly in the context of Sustainable Development Goal which aims to end preventable deaths of newborns and children under five (WHO, 2020; Blencowe et al., 2016).

METHOD

Data Source

Quarterly data from 2001 to 2020 were obtained from the Health Information Management Department, OAUTHC, Ile-Ife.

Model Selection Process

Stationarity Test: Augmented Dickey-Fuller (ADF) test was used to confirm stationarity.

Model Identification: ACF and PACF plots helped suggest potential ARMA models.

Model Selection: Models were compared using Akaike Information Criterion (AIC), Bayesian Information Criterion (BIC), and Hannan-Quinn Criterion (HQIC).

Diagnostic Checks: Residual plots and normality tests were used to confirm model adequacy.

Software Tools

Data analysis was conducted using Microsoft Excel and GRETL software.

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RESULT AND DISCUSSION

Livebirths

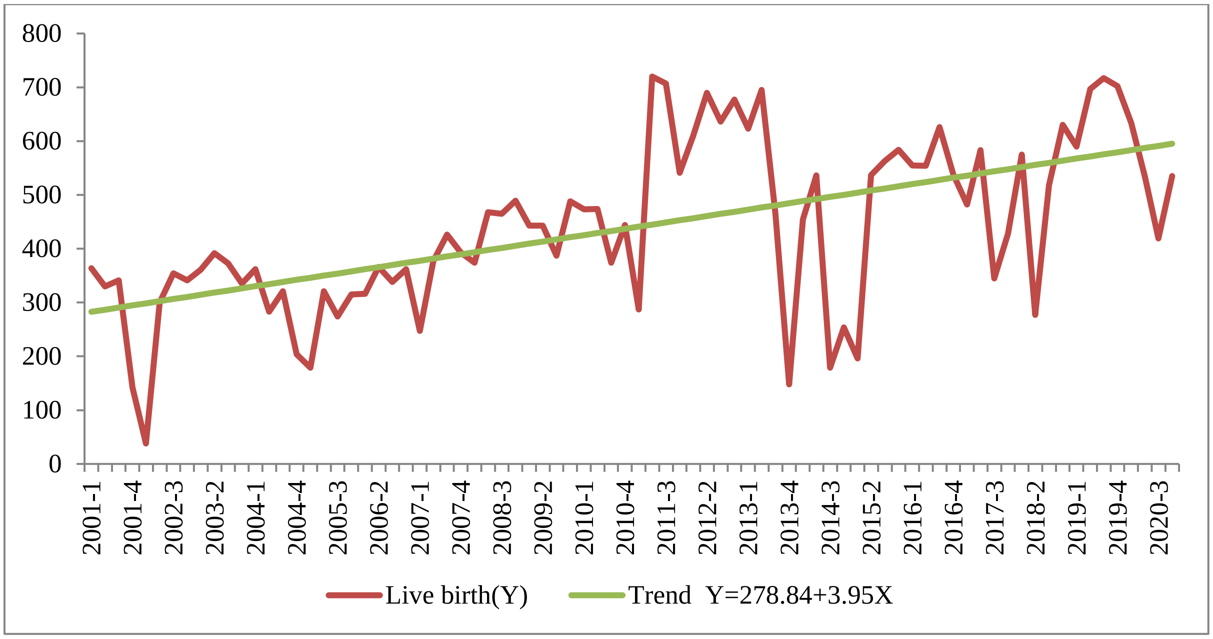

Figure 1: *Upward Linear Trend of Livebirth*

Figure 1: Shows an upward linear trend of livebirth was observed over the 20-year period which implies it is not a seasonal data.

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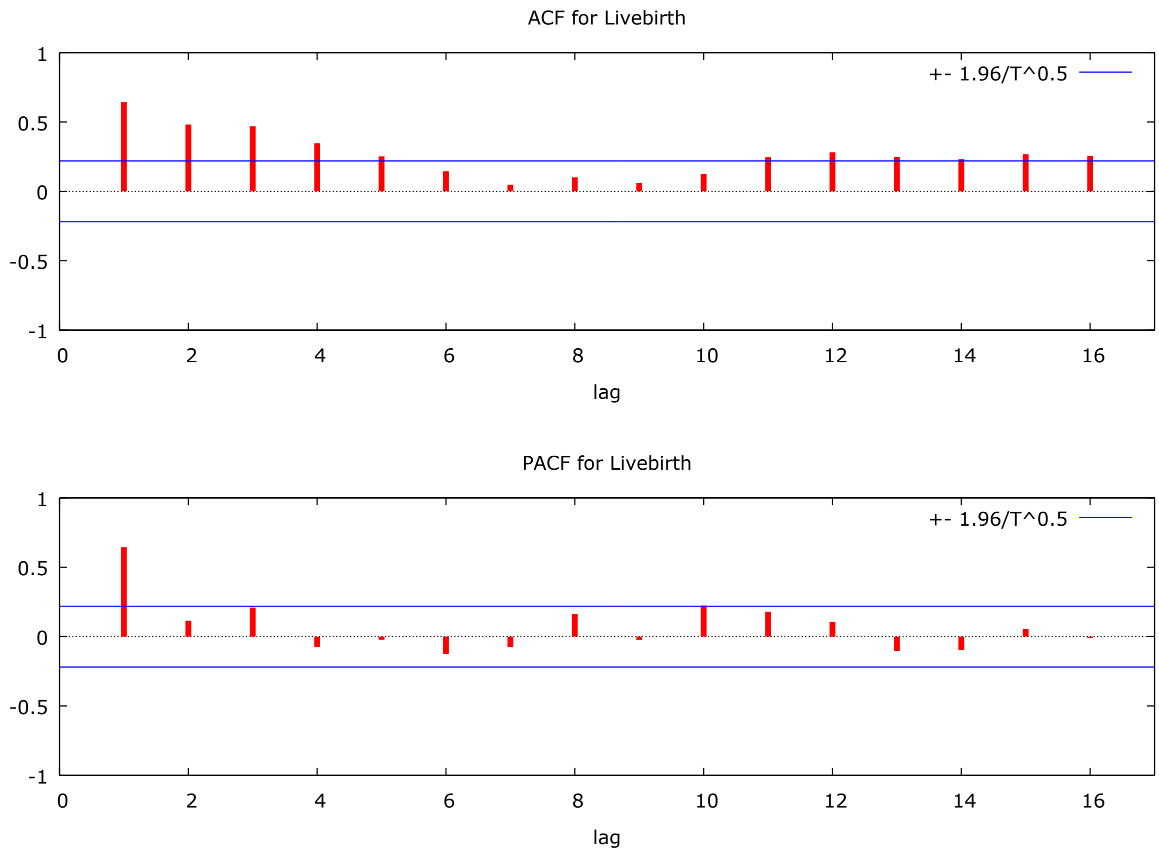

Figure 2: *ACF and PACF plots at original level of number of live birth from 2001 to 2020.*

Figure 2 above revealed that the first four lags in ACF plot exceeds the significance bounds, indicating the Prescence of autocorrelation in the series, similarly, the Partial Autocorrelation Function (PACF) plot reveals a significant spike at lag 1, with subsequent lags falling within the confidence limits. This suggests that the data may follow a mixed autoregressive moving average process, and potential candidate models include ARMA (1,1), ARMA(1,2), ARMA(1,3) and ARMA(1,4) models. These models are proposed for further evaluation based on model selection criteria such as AIC, BIC and residual diagnostics.

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Test of Stationary for live birth of the original data from 2001 to 2020

The test of stationary is done by using Augmented Dickey Fuller test

Ho: The series is not stationary

H1: The series is stationary

Test Statistic: $\alpha = 0.05$

Table 1: *Result for Augmented Dickey Fuller (ADF) test at original Level*

Augmented Dickey fuller	-0.352922
P-value	0.001950

Table 1 above revealed that the Augmented Dickey Fuller test returned a p-value less than 0.05 indicating that the null hypothesis of a unit root is rejected at the 5% significance level. This implies that the time series is stationary, as it exhibits a constant mean and variance over time. In other words, there is no evidence of a unit root, confirming that the series does not require differencing for stabilization.

Model Identification

To get an appropriate time series model, the smallest value of the Akaike (AIC), Schwarz, and Hannan Quinn Criterion of the identified model is selected.

Table 2: *Result for Model Identification using ARMA (p,q) for live birth*

S/N	Model	Akaike Information Criterion (AIC)	Schwarz Criterion (BIC)	Hannan Quinn Criterion (HQIC)
1.	ARMA(1,1)	996.8713	1006.399	1000.691

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2.	ARMA(1,2)	997.7951	1009.705	1002.570
3.	ARMA(1,3)	997.0495	1011.342	1002.780
4.	ARMA(1,4)	997.1770	1013.851	1003.862
5.	ÀRIMA(2,1)	998.4753	1010.385	1003.250
6.	ARIMA(2,2)	998.7319	1013.024	1004.462
7.	**ARMA(2,3)**	**990.1766**	1006.851	**996.8618**
8.	ARMA(2,4)	992.0821	1011.138	999.7223
9.	ARIMA(3,1)	997.8235	1012.116	1003.554
10.	ARMA(3,2)	999.8183	1016.493	1006.503
11.	ARMA(3,3)	992.0782	1011.134	999.7184
12.	ARMA(3,4)	992.3840	1013.822	1000.979
13.	ARMA(4,1)	999.8184	1016.493	1006.504
14.	ARMA(4,2)	992.8446	1011.901	1000.485
15.	ARMA(4.3)	994.0780	1015.516	1002.673
16.	ARMA(4,4)	993.1728	1016.993	1002.723

Table 2: reveals that among the evaluated models, ARMA(2,3) model recorded the lowest values for both the Akaike Information Criterion (AIC) and Hannan-Quinn Information Criterion (HQIC) when compared to other competing models. This suggests that ARMA(2,3) offers the best fit to the data based on these model selection criteria.

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Model Estimation

Table 3: *Result of the estimated parameter of ARMA for Live birth*

Model 1: ARMA, using observations 2001:1-2020:4 (T = 80)
Dependent variable: Livebirth
Standard errors based on Hessian

	Coefficient	*Std. Error*	*z*	*p-value*	
Const	440.808	34.8072	12.66	<0.0001	***
phi_1	1.50287	0.110711	13.57	<0.0001	***
phi_2	−0.725061	0.104091	−6.966	<0.0001	***
theta_1	−1.08199	0.140404	−7.706	<0.0001	***
theta_2	0.306297	0.191290	1.601	0.1093	
theta_3	0.452170	0.126634	3.571	0.0004	***

Mean dependent var	438.9875	S.D. dependent var	155.7042
Mean of innovations	−1.371321	S.D. of innovations	104.0612
R-squared	0.548518	Adjusted R-squared	0.524439
Log-likelihood	−488.0883	Akaike criterion	990.1766
Schwarz criterion	1006.851	Hannan-Quinn	996.8618

		Real	*Imaginary*	*Modulus*	*Frequency*
AR					
	Root 1	1.0364	-0.5524	1.1744	-0.0779
	Root 2	1.0364	0.5524	1.1744	0.0779
MA					
	Root 1	0.7671	-0.6416	1.0000	-0.1109
	Root 2	0.7671	0.6416	1.0000	0.1109
	Root 3	-2.2116	0.0000	2.2116	0.5000

The ARMA (2,3) model with equation

$$Y_t = 440.808 + 1.50286\phi_1 - 0.725061\phi_2 - 1.08199\theta_1 + 0.306295\theta_2 + 0.452171\theta_3$$

was estimated to assess the quarterly pattern of livebirths from 2021 to 2020, using 80 observations. The results presented in table 3 above show that constant term (440.808) is statistically significant (p<0.0001), indicating a stable average level of livebirths over the period.

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Both autoregressive components, ϕ_1 (1.50287) and ϕ_2 (-0.72506), were highly significant ($p<0.0001$), suggesting strong temporal dependence in the series. Similarly, two out of the three moving average terms, θ_1 (-1.08199) and θ_3 (0.45217), were significant ($p=0.1093$). The model explained approximately 55% of the variation in livebirths ($R^2=0.5485$), indicating a moderate goodness of fit. The standard deviation of the innovations (104.06) was lower than that of dependent variable (155.70), showing reduced unexplained variability after modeling. The roots of the AR components had moduli greater than one, confirming stationarity, while the MA roots indicated near invertibility, with one root at the boundary (modulus = 1.000). Overall, the model demonstrates a reasonably good fit for forecasting livebirths, with adequate stability and statistical significance in the key parameters. Furthermore, in the context of global health targets such as the Sustainability Development Goal (SDG) 3, which aims to ensure healthy lives and promote well being for all at all ages, predictive models like this can help track progress in maternal and child health. This model allow for early identification of trends and potential shortfalls, enabling evidences based interventions to reduce maternal and neonatal mortality.

Model Diagnostic Checking

Model diagnosis is done to check if the model selected is really the appropriate one. The following tests are applied to the residual.

Test for autocorrelation and partial Autocorrelation function

Hypothesis:

Ho: There is no autocorrelation within the residual of the fitted model

H_1: There is autocorrelation within the residual of the fitted model

Test Statistic: $\alpha=0.05$

Critical Value: Residual autocorrelation function ***, **, * indicate significance at the 1%, 5%, 10% levels using standard error 1/T^0.5

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Table 4: *Residual for Autocorrelation function for the number of Live birth*

LAG	ACF	PACF	Q-stat.	[p-value]
1	-0.0071	-0.0071		
2	-0.0103	-0.0103		
3	0.0327	0.0325		
4	0.0374	0.037		
5	0.0385	0.0388		
6	0.0796	0.0785	0.9158	[0.339]
7	-0.0701	-0.0666	1.3571	[0.507]
8	0.1782	0.1779	4.2511	[0.236]
9	-0.0434	-0.0501	4.4249	[0.352]
10	0.0289	0.0453	4.5034	[0.479]
11	0.1017	0.0826	5.4869	[0.483]
12	0.1028	0.1207	6.5064	[0.482]
13	-0.0202	-0.0261	6.5465	[0.586]
14	-0.0279	-0.0566	6.6237	[0.676]
15	0.0596	0.0971	6.9822	[0.727]
16	0.2161 *	0.1871 *	11.7708	[0.381]

Table 4 revealed that the null hypothesis of no autocorrelation in the residual is not rejected, as the p-value exceeds the 0.05 significance level. This indicates that there is no significant autocorrelation remaining in the residuals of the fitted model. Therefore, the ARMA(2,3) model appears to be an adequate fit for the data.

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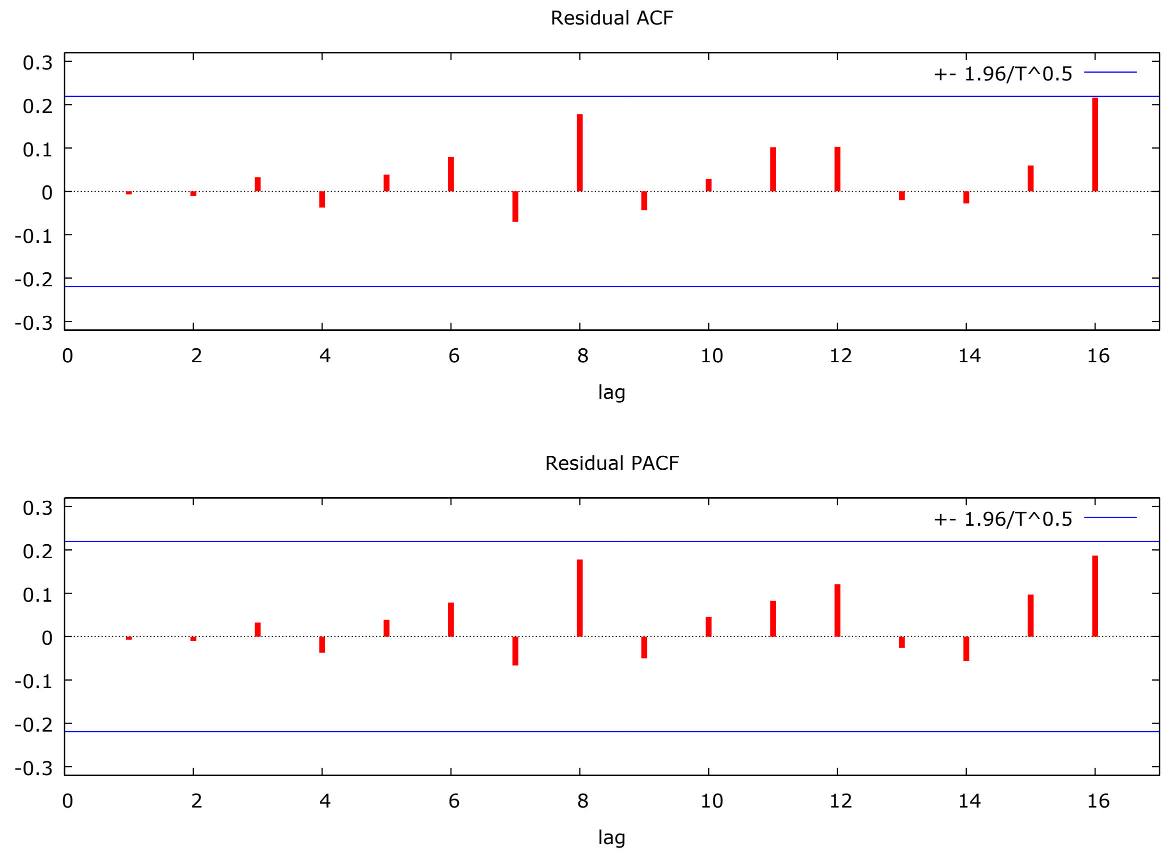

Figure 3: *Residual ACF and PACF of the Best ARIMA Model for Live birth*

Figure 3 revealed the correlogram of residuals, stating that the ACF and PACF plots of the residual from lag 1 to lag 16 show values that hover closely around the zero line, with no significant spikes. This indicates the absence of autocorrelation in the residuals, thereby confirming that the model is valid and adequately captures the underlying structure of the data.

Table 5: *Result for the Forecast of Live birth from 2021 to 2023*

For 95% confidence intervals, z(0.025) = 1.96

Observation	prediction	std. error	95% interval
2021:1	445.584	104.061	(241.627, 649.540)
2021:2	343.792	112.902	(122.508, 565.076)

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2021:3	325.178	115.072	(99.6400, 550.716)
2021:4	337.374	124.964	(92.4491, 582.298)
2022:1	369.199	137.392	(99.9153, 638.483)
2022:2	408.186	146.375	(121.296, 695.075)
2022:3	443.702	150.379	(148.964, 738.440)
2022:4	468.810	151.146	(172.570, 765.050)
2023:1	480.793	151.161	(184.523, 777.063)
2023:2	480.597	151.831	(183.013, 778.181)
2023:3	471.614	153.125	(171.495, 771.733)
2023:4	458.256	154.363	(155.710, 760.802)
2024:1	444.693	155.083	(140.736, 748.651)
2024:2	433.996	155.304	(129.606, 738.387)
2024:3	427.754	155.313	(123.347, 732.161)
2024:4	426.128	155.354	(121.641, 730.616)
2025:1	428.212	155.491	(123.455, 732.968)
2025:2	432.521	155.659	(127.435, 737.607)
2025:3	437.487	155.780	(132.164, 742.810)
2025:4	441.825	155.831	(136.403, 747.248)
2026:1	444.745	155.838	(139.308, 750.182)
2026:2	445.987	155.839	(140.548, 751.426)
2026:3	445.737	155.852	(140.273, 751.201)
2026:4	444.460	155.873	(138.955, 749.966)

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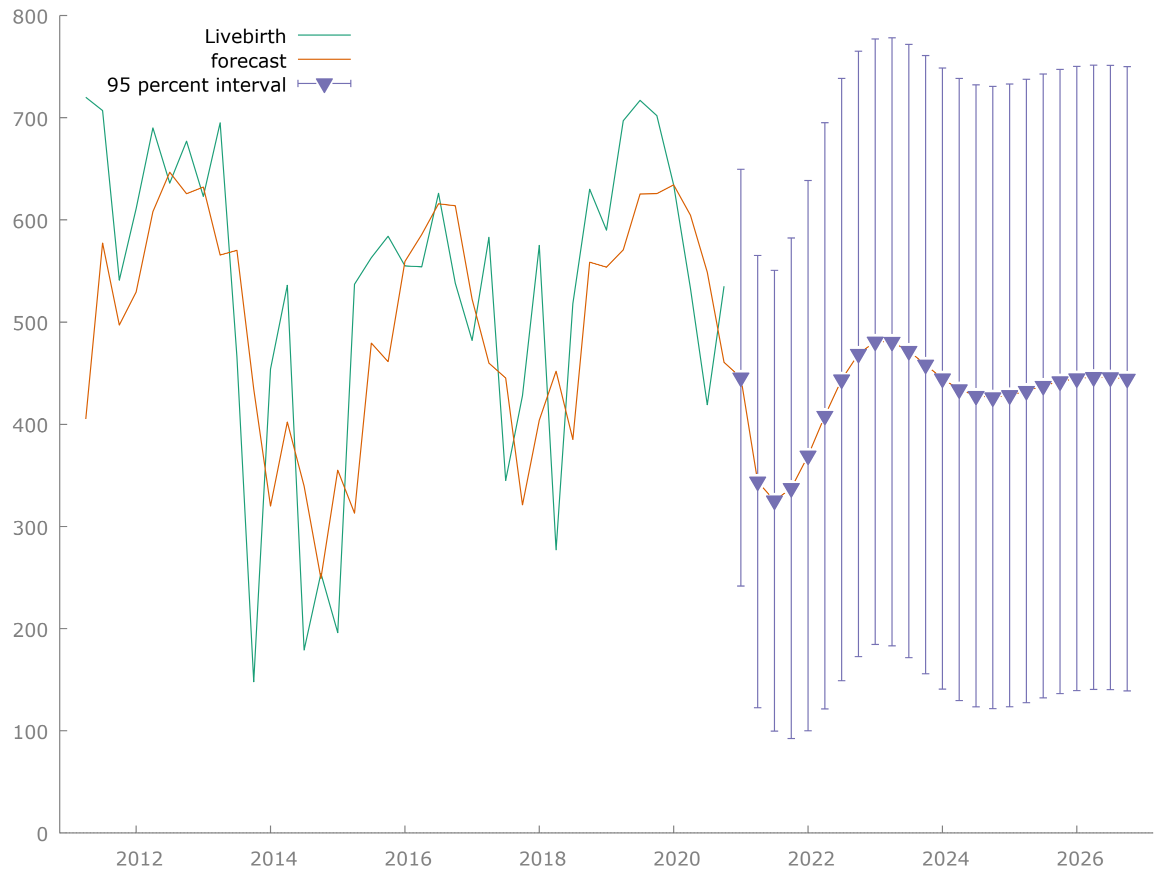

***Figure 4:** Forecast of Live birth from 2021 to 2026*

Table 5 and Figure 4 above revealed the forecasted values of livebirths from the first quarter of 2021 to the fourth quarter of 2026 reveal a dynamic trend with key implication for public health planning. Initially, the predicted number of livebirths declines from 445.584 in 2021:1 to 325.178 in 20121:3, followed by gradual recovery and sustained growth peaking at 480.793 in 2023:1. From that point, the forecast shows a mild decline, stabilizing around the mid 440s by 2026. The 95% confidence interval, computed using a z-score of 1.96, indicate increasing uncertainty in the forecast over time, as reflected in the widening intervals. This suggests that while the central predictions remain relatively stable in later years, the degree of variability is significant and must be considered in healthcare resource planning. A narrowing of the gap between the lower and upper

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bounds from 2023 onward indicates improved predictability, potentially due to stabilization in birth patterns. These forecasts emphasize the importance of strengthening maternal and child health services, especially in anticipation of periodic increase in livebirths.

Stillbirths

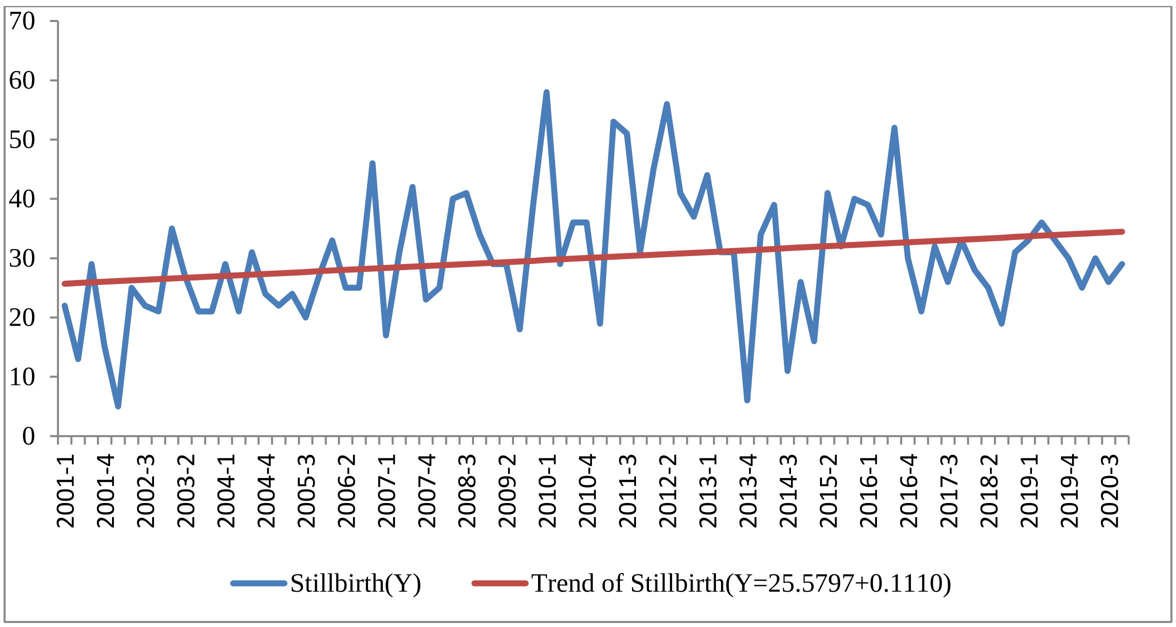

Figure 5: *Upward Linear Trend of Stillbirth*

Figure 5: Shows a linear increasing trend of stillbirths, less pronounced than livebirths, which implies it is not a seasonal data since it does not follow a regular pattern and also has a trend.

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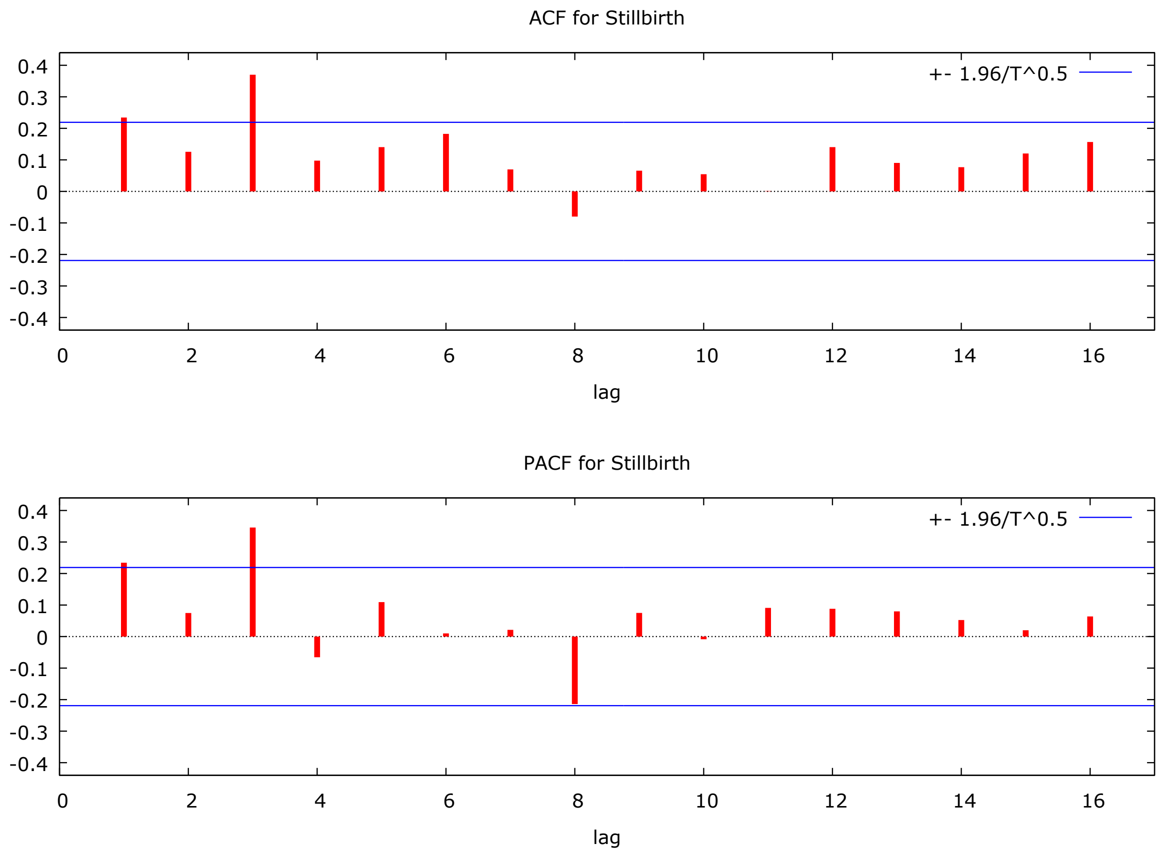

***Figure 6:** ACF and PACF plots at original level of number of Stillbirth from 2001 to 2020*

Figure 6 above revealed that the first and the third lags in ACF plot exceeds the significance bounds, indicating the Prescence of autocorrelation in the series, similarly, the Partial Autocorrelation Function (PACF) plot reveals a significant spike at lag 1 and lag 3, with the remaining lags falling within the confidence limits. This suggests that the data may follow a mixed autoregressive moving average process, and potential candidate models include ARMA (1,1), ARMA(1,3), ARMA(3,1) and ARMA(3,3) models. These models are proposed for further evaluation based on model selection criteria such as AIC, BIC and residual diagnostics.

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Table 6: Result for Augmented Dickey Fuller (ADF) test at Original Level of number of stillbirth

Augmented Dickey fuller	-0.765746
P-value	1.609e-007

Table 6 above revealed that the Augmented Dickey Fuller test returned a p-value less than 0.05 indicating that the null hypothesis of a unit root is rejected at the 5% significance level. This implies that the time series is stationary, as it exhibits a constant mean and variance over time. In other words, there is no evidence of a unit root, confirming that the series does not require differencing for stabilization.

Model Identification

To get an appropriate time series model, the smallest value of the Akaike, Schwarz, and Hannan Quinn Criterion of the identified model is selected.

Table 7: *Result for model identification ARMA (p,q) for number of Stillbirth*

S/N	Model	Akaike Information Criterion (AIC)	Schwarz Criterion (AIC)	Hannan-Quinn Criterion (HQIC)
1.	ARMA(1,1)	600.6147	610.1428	604.4348
2	ARMA(1,2)	602.6021	614.5122	607.3772
3	**ARMA(1,3)**	**597.7584**	612.0506	**603.4885**
4	ARMA(1,4)	599.0405	615.7147	605.7257
5	ARMA(2,1)	602.6082	614.5183	607.3833

6	ARMA(2,2)	599.5910	613.8832	605.3212
7	ARMA(2,3)	598.3764	615.0506	605.0616
8	ARIMA(2,4)	600.3763	619.4325	608.0165
9	ARMA(3,1)	598.1364	612.4286	603.8666
10	ARMA(3,2)	598.2832	614.9574	604.9683
11	ARMA(3,3)	600.2506	619.3069	607.8908
12	ARMA(3,4)	602.2506	623.6889	610.8458

Table 7: reveals that among the evaluated models, ARMA(1,3) model recorded the lowest values for both the Akaike Information Criterion (AIC) and Hannan-Quinn Information Criterion (HQIC) when compared to other competing models. This suggests that ARMA(1,3) offers the best fit to the data based on these model selection criteria.

Model Estimation

Table 8: *Result of the estimated parameter of ARMA of still birth*

Model 2: ARMA, using observations 2001:1-2020:4 (T = 80)
Dependent variable: Stillbirth
Standard errors based on Hessian

	Coefficient	***Std. Error***	***z***	***p-value***	
const	29.7229	2.25695	13.17	<0.0001	***
phi_1	0.677339	0.165183	4.101	<0.0001	***
theta_1	−0.444816	0.193571	−2.298	0.0216	**
theta_2	−0.255970	0.133428	−1.918	0.0551	*
theta_3	0.412025	0.131434	3.135	0.0017	***

Mean dependent var	30.07500	S.D. dependent var	10.48902
Mean of innovations	0.147349	S.D. of innovations	9.370094
R-squared	0.193885	Adjusted R-squared	0.162064

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Log-likelihood	−292.8792	Akaike criterion	597.7584
Schwarz criterion	612.0506	Hannan-Quinn	603.4885

		Real	*Imaginary*	*Modulus*	*Frequency*
AR					
	Root 1	1.4764	0.0000	1.4764	0.0000
MA					
	Root 1	1.0088	0.8487	1.3183	0.1113
	Root 2	1.0088	-0.8487	1.3183	-0.1113
	Root 3	-1.3964	0.0000	1.3964	0.5000

ARMA(1,3) model with equation $Y_t = 29.7229 + 0.677339\phi_1 - 0.444816\theta_1 - 0.255970\phi_2 + 0.412025\phi_3$ estimated a statistically significant autoregressive component (ϕ_1=0.677, p<0.0001), suggesting that the current number of stillbirths is strongly influenced by the preceding quarter. Additionally, three moving average components were included with θ_1(-0.446, p=0.0216), θ_2(-0.256, p = 0.0551) and θ_3(0.412, p = 0.0017) being statistically significant indicating that random shocks in stillbirths persist but diminish over time. The constant term (29.72) reflects the average underlying level of stillbirths after accounting for temporal dependencies. However, the relatively low R^2(0.19) implies that the model explains only 19% of the variation in stillbirths, suggesting other observed factors such as maternal health, healthcare access, or socio-economic conditions may play significant roles.

Model Diagnostic Checking

Model diagnosis is done to check if the model selected is really the appropriate one. The following tests are applied to the residual.

Test for autocorrelation and partial Autocorrelation function

Hypothesis:

H_0: There is no autocorrelation within the residual of the fitted model

H_1: There is autocorrelation within the residual of the fitted model

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Test Statistic: α=0.05

Critical Value: Residual autocorrelation function indicate significance at the 1%, 5%, 10% levels using standard error 1/T^0.5

Hypothesis:

H_0: There is no autocorrelation within the residual of the fitted model

H_1: There is autocorrelation within the residual of the fitted model

Test Statistic: α=0.05

Critical Value: Residual autocorrelation function indicate significance at the 1%, 5%, 10% levels using standard error 1/T^0.5

Table 9: *Residual for Autocorrelation Function for the Number of Stillbirths*

LAG	ACF	PACF	Q-stat.	[p-value]
1	-0.0212	-0.0212		
2	0.0620	0.0616		
3	0.0156	0.0183		
4	-0.1398	-0.1436		
5	0.0327	0.0256	2.1623	[0.141]
6	0.0389	0.0600	2.2968	[0.317]
7	0.0493	0.0526	2.5153	[0.473]
8	-0.1560	-0.1884 *	4.7312	[0.316]
9	-0.0071	-0.0136	4.7359	[0.449]
10	-0.0292	0.0115	4.8155	[0.568]
11	0.0646	-0.0473	5.2127	[0.634]
12	0.1064	0.0512	6.3057	[0.613]
13	0.0142	0.0294	6.3253	[0.707]

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14	0.0904	0.1002	7.1369	[0.712]
15	0.0808	0.0827	7.7952	[0.732]
16	0.1612	0.1637	10.4588	[0.576]

Table 9 revealed that the null hypothesis of no autocorrelation in the residual is not rejected, as the p-value exceeds the 0.05 significance level. This indicates that there is no significant autocorrelation remaining in the residuals of the fitted model. Therefore, the ARMA(1,3) model appears to be an adequate fit for the data.

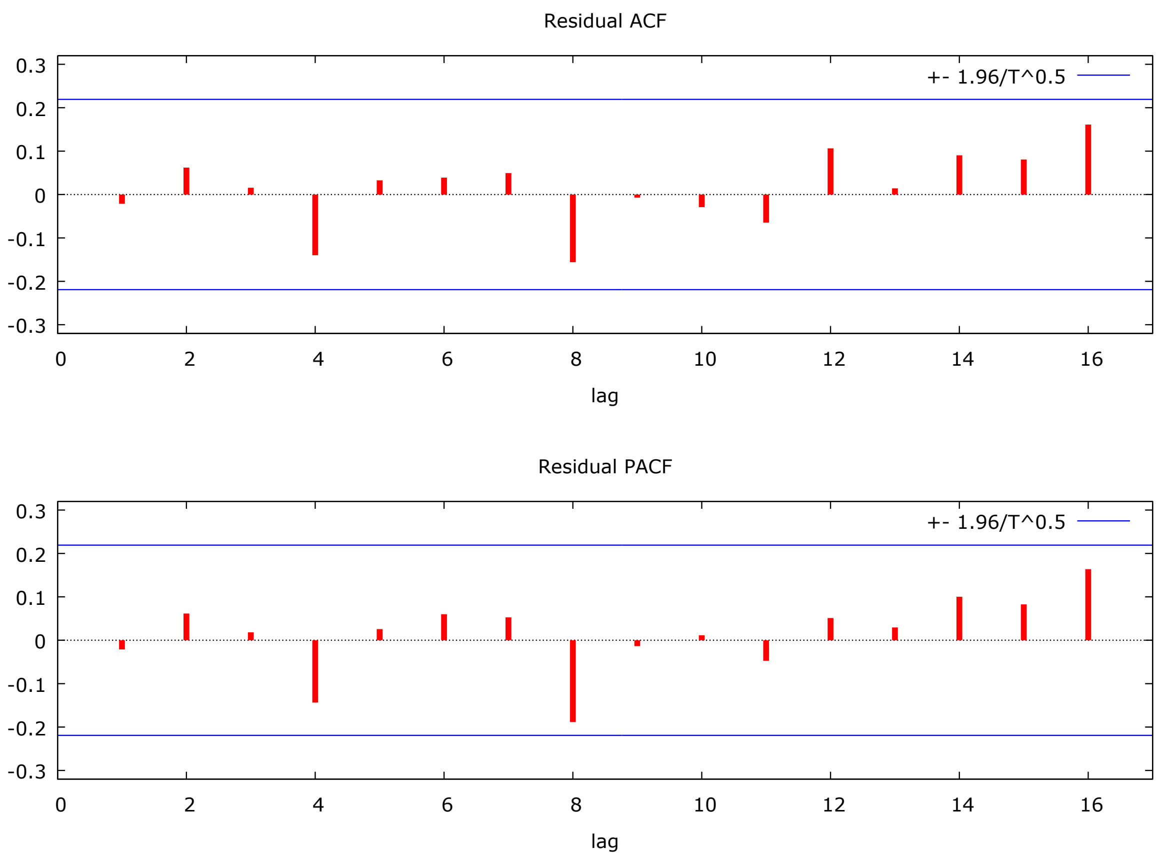

Figure 7: *Residual ACF and PACF of the Best ARIMA Model for Stillbirth*

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Figure 7 revealed the correlogram of residuals, stating that the ACF and PACF plots of the residual from lag 1 to lag 16 show values that hover closely around the zero line, with no significant spikes. This indicates the absence of autocorrelation in the residuals, thereby confirming that the model ARMA(1,3) is valid and adequately captures the underlying structure of the data.

Table 10: *Result for the Stillbirth Forecast from year 2021 to 2023*

For 95% confidence intervals, z(0.025) = 1.96

Observation	prediction	std. error	95% interval
2021:1	29.7517	9.37009	(11.3867, 48.1168)
2021:2	26.4700	9.62007	(7.61505, 45.3250)
2021:3	28.3299	9.66421	(9.38836, 47.2714)
2021:4	28.7793	10.1915	(8.80434, 48.7544)
2022:1	29.0838	10.4245	(8.65212, 49.5155)
2022:2	29.2900	10.5297	(8.65220, 49.9278)
2022:3	29.4297	10.5776	(8.69799, 50.1614)
2022:4	29.5243	10.5995	(8.74967, 50.2989)
2023:1	29.5884	10.6095	(8.79408, 50.3827)
2023:2	29.6318	10.6141	(8.82847, 50.4351)
2023:3	29.6612	10.6162	(8.85373, 50.4686)
2023:4	29.6811	10.6172	(8.87175, 50.4904)
2024:1	29.6946	10.6177	(8.88437, 50.5048)
2024:2	29.7037	10.6179	(8.89311, 50.5143)
2024:3	29.7099	10.6179	(8.89911, 50.5207)
2024:4	29.7141	10.6180	(8.90322, 50.5250)
2025:1	29.7169	10.6180	(8.90602, 50.5279)
2025:2	29.7189	10.6180	(8.90792, 50.5298)
2025:3	29.7202	10.6180	(8.90922, 50.5311)
2025:4	29.7210	10.6180	(8.91010, 50.5320)
2026:1	29.7216	10.6180	(8.91069, 50.5326)
2026:2	29.7220	10.6180	(8.91110, 50.5330)
2026:3	29.7223	10.6180	(8.91137, 50.5333)
2026:4	29.7225	10.6180	(8.91156, 50.5335)

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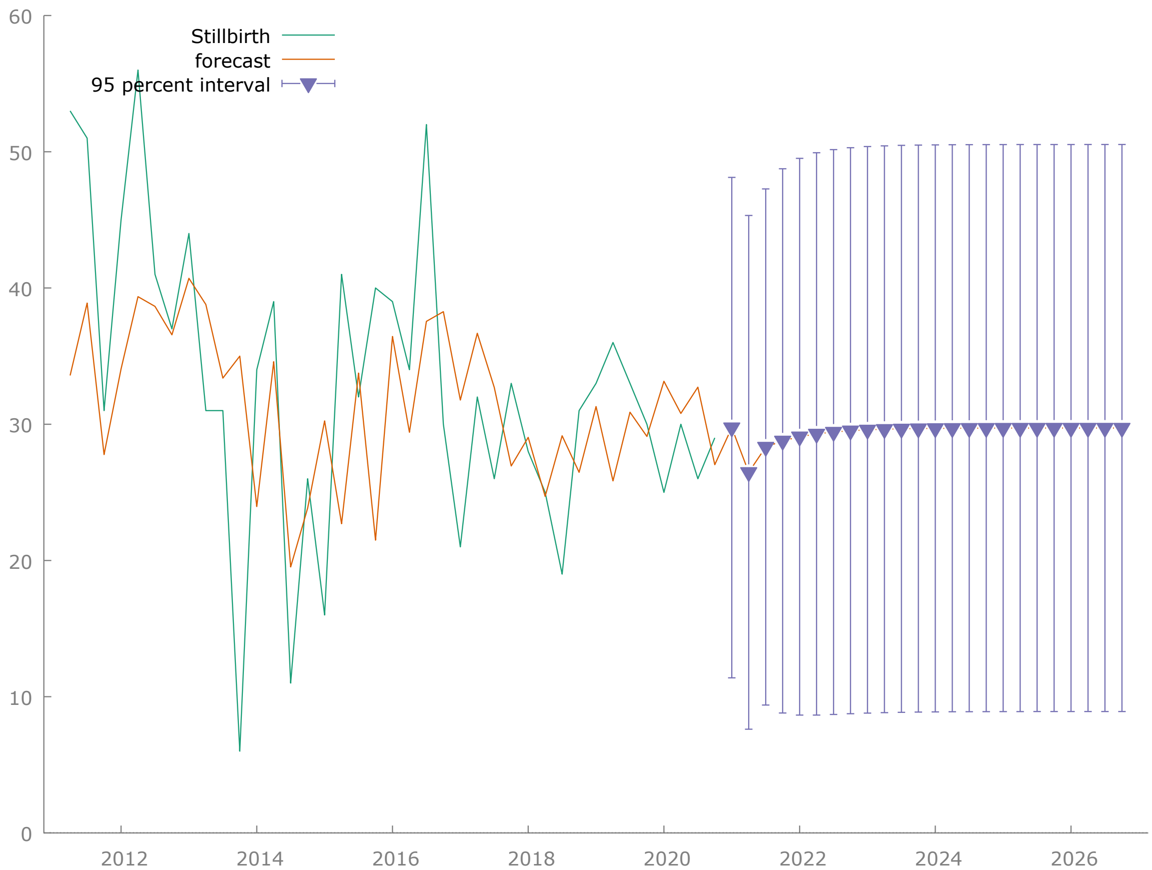

Figure 8: *Forecast of Stillbirths From 2021 to 2026*

Table 10 and Figure 7 above revealed the forecasted values of stillbirths from 2021 to 2026 indicate a relatively stable trend, with point estimates hovering around 29 to 30 cases per quarter. While the central predictions suggest little variation over time, the associated 95% confidence intervals highlight considerable uncertainty, particularly in the earlier years. As the forecast progresses, the prediction intervals narrow slightly and stabilize suggesting increasing confidence in rge estimates as the model settles around a long term average. However, with standard errors remaining above 10, the range of the outcomes remain wide, implying that unexpected surges in stillbirths remain possible.

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The ARMA model estimations and forecasts for livebirths and stillbirths reveal critical patterns with direct implications for maternal and healthcare planning. The livebirths forecast shows a fluctuating trend with gradual stabilization, while stillbirths remain relatively constant around 30 cases per quarter, though with wide confidence intervals early in the forecast. However, the relatively low R^2 values, especially for stillbirths, suggest that other unmeasured factors such as healthcare access, socio-economic conditions, or maternal risk factors may be influential. These findings underscore the importance of continuous improvement in maternal healthcare, data-driven planning and timely intervention,

CONCLUSION

The ARMA models provided a good fit for the birth data and proved effective in forecasting future values. Based on these findings, hospital management is encouraged to continue improving maternal health services, promote facility-based deliveries, and regularly monitor and evaluate interventions using hospital data. These steps are essential to enhance the quality of care and ensure better maternal and neonatal outcomes.

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