International Journal of Applied Mathematics and Statistics,
Int. J. Appl. Math. Stat.; Vol. 52; Issue No. 1; Year 2014,
ISSN 0973-1377 (Print), ISSN 0973-7545 (Online)

ARIMA-NOISE MODEL FOR A SEGMENTED INTERVENTION ANALYSIS OF MATERNAL HEALTH POLICY ON ASSISTED DELIVERY

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ABSTRACT

Women's utilization of maternal health care facility is a vital health issue with regards to well-being and survival of both the mother and her child. In April 2005, the government of Ghana in pursuit of Millennium Development Goal 5 (MDG 5) established the Exemption Fee Delivery policy (EFDP) and subseqently followed by Free Maternal Healthcare Policy (FMHCP) in july 2008. This was to help tackle the high incidence of maternal mortality and replace the cash and carry healthcare system. Using intervention analysis of Box and Tiao(1975) this study assessed the impact of these policies on monthly assisted childbirths at Kwame Nkrumah University of Science and Technology hospital from January 2000 to December 2011. The estimated intervention model showed an insignificant approximate increase of 9 childbirths for the EFDP. The FMHCP showed a significant additional 60 childbirths at the hospital. Findings show that the elimination of financial barrier to seeking assisted childbirth resulted in a significant increase in the number of pregnant women seeking assisted delivery. This confirms the assertion that financial factor is a barrier to assisted delivery and these policies had contributed in lowering infant and maternal death statistics.

Keywords: Maternal healthcare, Exemption Fee Delivery , Free Maternal HealthCare, Segmented intervention analysis.

2010 Mathematics Subject Classification: 37M10, 91B84.

1 Introduction

Childbirth is the shortest and most critical period of the pregnancy-childbirth continuum because most maternal deaths occur during childbirth (Reviani, 2010). The threat for a woman in this state is worsened when she has no access to proper health service due to poverty. The

lifetime risk of dying due to maternal health causes is about one in six in the poorest countries, compared with about one in 30,000 in the Western World (Fiagbe et al., 2012) . More than 536,000 women die yearly, while more than 1,500 women die every day in the world from pregnancy or childbirth- related complications because of poor access to delivery and obstetric services (WHO/UNICEF, 2005). Unfortunately 99 % of all these maternal deaths happen in developing countries (where 85 % of the world's population live) because of limited access to health delivery due to poverty.

Nonetheless death from pregnancy-related causes represents one of the most preventable sort of female deaths worldwide (Fiagbe et al., 2012). Financial barriers is seen an important obstacle for accessing emergency obstetric care and delivery service as well as contributing factor to the slow reduction in the level of maternal mortality (Bennis and De-Brouwere, 2012). Healthcare expenditure affect accessible resources by reducing the share of income available to be spent on other needs of the family by putting pressure on the household income (Blanchet et al., 2012) . If this obstacle is eliminated, it is believed that more pregnant women will have access to obstetric care during labour thereby reducing maternal mortality and the household income spent on delivery cost.

In April 2005, the government of Ghana in an effort to eliminate this barrier established a national policy to exempt pregnant women from delivery charges but were still made to pay fees through the National Health Insurance Scheme (NHIS) or out-of-pocket payments. The policy was shortly replaced with the Free Maternal Care Policy, instituted through a Presidential directive in July 2008 (Omane-Adjepong et. al ,2012). Under the FMHCP, pregnant women were not required to pay any enrolment premium with regards to NHIS. Pregnant women who could not attend maternity services due to financial constraints now had free access to full maternity services such as antenatal, perinatal and postnatal care (NHIA, 2008). There is therefore the need to assess the impact of these policies and how the targeted population had responded. It will also help to confirm the assertion that financial factor is a key obstacle that prevents pregnant women from accessing health services. This study assessed the impact of these policies on assisted childbirths at KNUST Hospital, Kumasi Ashanti region of Ghana. The Hospital serves a population of over 205,000. This comprise of 25000 students and about 150,000 people from over 30 surrounding communities, including Ayigya, Bomso, Ayeduase, Kotei, Boadi, Top High, Susanso, Oduom, Deduako, Maxima, etc. (www.knust.edu.gh). The aim of this study is to quantify the impact of exemption fee delivery and Free Maternal Care policy on the incidence of childbirth implemented by the Government via the National Health Insurance Scheme (NHIS) to improve maternal healthcare in the country more specifically at KNUST Hospital.

Ghana Maternal Healthcare Policy

Under the FMHCP, pregnant women are eligible for free health service in all NHIS accredited healthcare facilities public, mission or private. The basic objective of these policies is to provide

free and quality maternal healthcare service delivery in accredited facilities. In addition, it is expected to reduce infant and maternal mortality rates and to inspire women to seek antenatal and post natal care at accredited health facilities. All pregnant women and nursing mothers registered as well as babies born to mothers registered under the program up to 90 days after birth can benefit from the policy once certified by a doctor/nurse/midwife. The pregnant women are also exempted from NHIS premium and registration fee as well as medical services during postnatal, antenatal and delivery periods (including Caesarean delivery). There will be no waiting period between registering and accessing of healthcare services by the pregnant women.

2 Intervention Analysis Approach

Time series analysis has several applications in assessing the effects of policies. Chen and Zhou, (2013) used vector auto-regress model to analyse the impact of Foreign Direct Investment (FDI) on economic growth in China. Based on the vector auto-regress model, FDI increase of 1% will result in a 0.79% increase in gross domestic product in the next period. Intervention analysis of Box and Tiao (1975) is mostly concerned with assessing the events that occasionally cause disturbances in the patterns of the observed time series data. The technique has been applied in sectors such as Political Science, Economics , Sociology , Psychology and Education to measure the impact of a policy where more conventional experimental techniques would be inappropriate (McDowall et. al. 1980). To quantify the impact of these intervention policies on healthcare for women, monthly data on assisted childbirth was obtained from the Bio-Statistics Department of the Obstetrics & Gynecology directorate of KNUST Hospital in Kumasi for the period 2000 - 2011 analysed using R version 2.14.1 .

The impact assessment of a policy with intervention analysis can be specified by two main dimensions. These are duration and nature of the impact of the policy on the series being studied. A simple way to study intervention analysis is to consider some simple dynamic models. These are (a) the pulse function and (b) the step function. A pulse function $f(I_t)$ indicates that the intervention only occurs in the single time index t_0 thus, one large increase that lasts a very short time:

$$f(I_t) = P_t^{t_0} = \begin{cases} 0 & \text{if } t = t_0 \\ 1 & \text{if } t \neq t_0 \end{cases} \tag{2.1}$$

where $P_t^{t_0}$ is the pulse function and t_0 is the policy time. Consider monthly delivery in a hospital as used in this study, if a free delivery policy is in effect only for a given month , then we use a pulse function to indicate the existence of the policy. On the other hand if $f(I_t)$ is a step function then the intervention continues to exist starting with the time index t_0 . Thus, one large step leading to a new level. The intervention indicator is coded 0 prior to the commencement

of the event and as 1 at both the onset (t_0) and entire duration of the presence of the event:

$$f(I_t) = S_t^{t_0} = \begin{cases} 0 & \text{if } t < t_0 \\ 1 & \text{if } t \geq t_0 \end{cases} \tag{2.2}$$

The model is of the general form

$$Y_t = \sum_{t=1}^{n} f(I_t) + N_t \tag{2.3}$$

where $f(I_t)$ is the intervention function at time t, I_t is the impact at t, N_t is the function of the ARIMA preintervention noise model and Y_t is the response series.

3 Intervention Model Specification

The intervention programmes were implemented in April 2005 and July, 2008 directing all healthcare delivery facilities to exempt pregnant women from delivery and total treatment charges respectively. The event is modelled with step intervention functions due to the form of its occurrences. The hypothesized intervention model for this study is written as:

$$Y_t = c + w_1 I_{(1t)} + w_2 I_{(2t)} + N_t \tag{3.1}$$

where,

$$I_{(1t)} = S_t = \begin{cases} 1 & April, 2005 \leq t \leq June, 2008 \\ 0 & otherwise \end{cases} \tag{3.2}$$

$$I_{(2t)} = S_t = \begin{cases} 1, & t \geq July, 2008 \\ 0 & otherwise \end{cases} \tag{3.3}$$

Y_t is the increase or decrease in monthly deliveries recorded at the hospital; I_{1t} represents a step function for the exemption from delivery fee, I_{2t} represent a step function for the Free Maternal Care Policy, N_t is the function of the ARIMA preintervention noise, w_1 and w_2 are the impact parameters which indicate the magnitude of the impact and c is a constant term.

The general modeling approach of the ARIMA model proposed by Box and Jenkins(1976) are model identification , estimation and validation. The form and order of tentative ARIMA models are specified under the identification stage by using the sample partial auto-correlogram function (PAC) and auto-correlogram (AC). For the AR model the AC dies down and the PAC cuts off after lag q. While for the MA model AC cut off after lag p and PAC dies down. Nonetheless, the observed series must pass stationary test (mean and variance not changing over time) before the identification of models. The stationary tests in this study were Augmented Dickey-Fuller and Kwiatkowski, Phillips, Schmidt and Shin Test (1992). KPSS test is used for verifying whether a time series is stationary for null hypothesis, while Augmented Dickey-Fuller test is used for verifying whether the series has unit root. Both tests will be conducted at 5 % level of significance . The Model Estimation stage consists of deciding the form of the model to be considered and significance test of model parameters. The popular maximum likelihood method

was used in the estimation of the parameters. Final fitted adequate models were based on the Schwarz Bayesian information criterion (BIC) with the smallest value related to the optimal model (Robert and McGee, 2000). At the Diagnostic stage the adequacy of the optimal model is checked based on residual analysis and the Ljung-Box test of goodness of fit. The ARIMA-Intervention model would be considered as an adequate fit for the response series if it passes all the above test. The analysis of the study was carried out based on the results obtained from the data, using the R version 2.14.1 statistical package (R Development Core Team, 2010).The pre-intervention period spans from January 2001 to March 2005, while the post-intervention marked the period from April 2005 to December 2011.

4 Empirical results

4.1 Time plot analysis

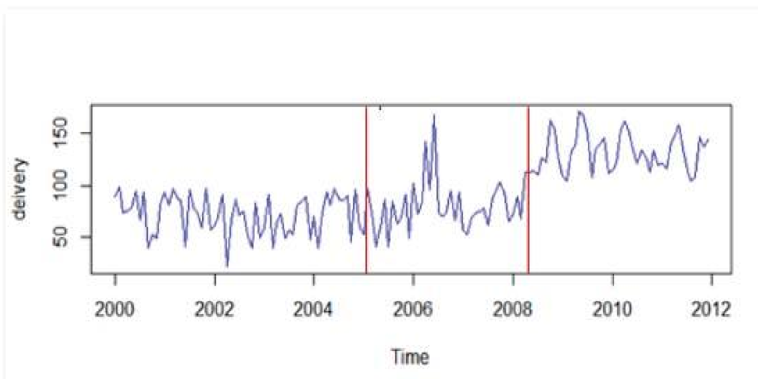

Figure 1: Time plot of Monthly Delivery from 2000 to 2011

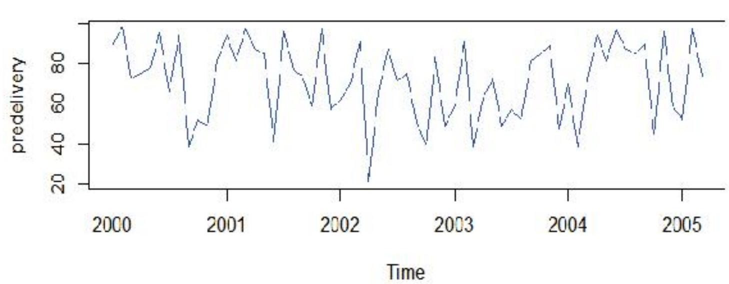

Figure 2: Time plot of pre-intervention series

The time plot of monthly assisted deliveries recorded in the hospital from 2000 to 2011 is presented in figure 1 while figure 2 shows the time plot for preintervention period from 2000 to march ,2005 . The highest number of recorded assisted monthly childbirth was in June 2009

(171) which fell in the Free Maternal Health Care policy period with the minimum in may 2003 (21) of the EFCP period. The range of monthly assisted deliveries for the pre-intervention period is recorded to be between 21-98 and that of the post-intervention is from 41-171.

4.2 ARIMA-noise model results

The p -value (0.1) of the KPSS test is greater than the level of significance(5%), so we failed to reject the null hypothesis that the data is level or trend stationary. While the p value(0.01) of ADF test is smaller than the level of significance (5%) as shown in Table 1, so we reject the null hypothesis that data has a unit root thus a stationary data set.

Table 1: Unit root and stationarity tests for preintervention series

Type of Test	Test Statistic	Critical Value	Lag order	$\alpha - level$
ADF	-5.2295	-3.45	15	0.05
KPSS	0.1609	0.4630	15	0.05

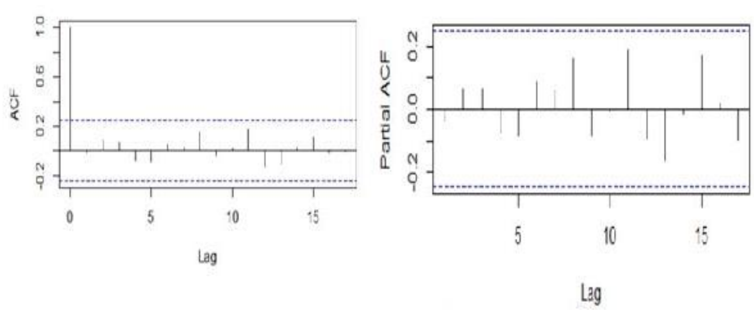

Figure 3: Sample ACF and PACF on monthly assisted delivery

The following non-seasonal candid models were selected for investigations based on the auto-correlogram and partial autocorrelogram in figure 3: ARIMA (1, 0, 0); ARIMA (1, 0, 1); ARIMA (1, 0, 2) and ARIMA (2, 0, 1) with their AICc and BIC in Table 2. ARIMA (1, 0, 1) had the smallest AICc and BIC and hence was considered as the preferred model.

Table 2: Penalty function statistics of candidate models

	ARIMA(1,0,0)	ARIMA(1,0,1)	ARIMA(1,0,2)	ARIMA(2,0,1)
AICc	557.51	556.92	559.92	560.01
BIC	561.63	560.8	569.58	569.68

Parameters AR(1) and MA(1) lie within the significance bounds with absolute values of 0.8449 and 0.8282 respectively. All the parameters had t-values that are greater than 1.96 (Table 3). Hence Arima(1,0,1) can be considered as an adequate model and must be maintained as an adequate pre-intervention noise model. The coefficient of the noise model AR(1) and MA(1) are statistically different from zero and strictly conforms to the bounds of parameter stationarity (ie.,$\phi_1 < 1$) (Table 3).

Table 3: Estimate of Parameters for ARIMA (1, 0, 1)

Coefficients	Estimate	STD error	t-value
Ar(1)	0.8449	0.3972	2.1271
Ma(1)	-0.8282	0.4069	-2.0354
Intercept	71.8959	2.7263	26.3712

The adequacy of the chosen noise model was checked using the Ljung-Box test and residual analysis. With a p-value (0.6401) greater than 0.05 (5 % significance level), results of the Ljung-Box test did not reject randomness of the error terms based on the first 24 autocorrelations of the residuals (Chi-square=24.8 ; p-value=0.640). This implies that the chosen noise model fits the pre-intervention data quite well. Clearly, there are no significant spikes from the ACF and PACF residual plots of the noise model as shown in Figure 4. This indicates that the residuals of the fitted noise model follow a white noise process.

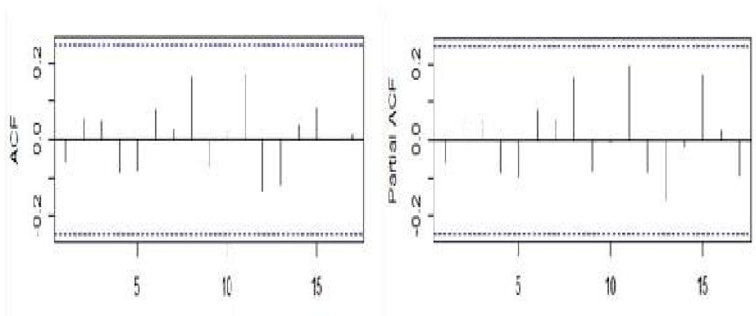

Figure 4: ACF and PACF of selected noise model residuals

The fitted noise model could then be written as :

$$Y_t = 71.8959 + 0.8449y_{t-1} - 0.8282\varepsilon_{t-1} + \varepsilon_t \tag{4.1}$$

4.3 ARIMA-Intervention model results

After selecting a suitable noise model to represent the pre-intervention data, the model is fitted together with a dichotomous intervention function. The dichotomous intervention function

consist of the presence of the policy (coded as 1) and as 0, in the absence of the policy. Table 4. provides a summary of the result for the estimated model.

Table 4: Parameter Estimates for the hypothesized Impact model

coefficients	Estimates	STD error	t-value
Ar(1)	0.3633	0.1259	2.8856
Ma(1)	-0.3656	0.1390	-2.6302
Intercept	71.9754	3.0011	23.9830
Delivery	9.1821	4.8648	1.8874
Free Care	60.1021	4.7164	12.7432

AIC=1288.39, AICc=1289.01 and BIC =1306.21

The full ARIMA-Intervention model is of the form:

$$Y_t = 71.9754 + 9.1821 I_{1t} + 60.1021 I_{2t} + 0.3633 y_{t-1} - 0.3656 \varepsilon_{t-1} + \varepsilon_t \qquad (4.2)$$

The Exemption Fee Delivery policy recorded an insignificant increase of about 9 monthly assisted delivery whilst Free Health Care policy recorded significant increase of about 60 monthly assisted deliveries as shown in Table 4. The residuals of the ARIMA-Intervention model were further investigated based on residual correlograms and the Ljung-Box test of goodness of fit. Results from this test indicate that the ARIMA-Intervention model fits the data reasonably well (Chi-square=15.37; p-value=0.222). The spikes of the ACF and PACF residual correlogram of the intervention model (in Figure 5) below did not show much deviation from a white noise residual.

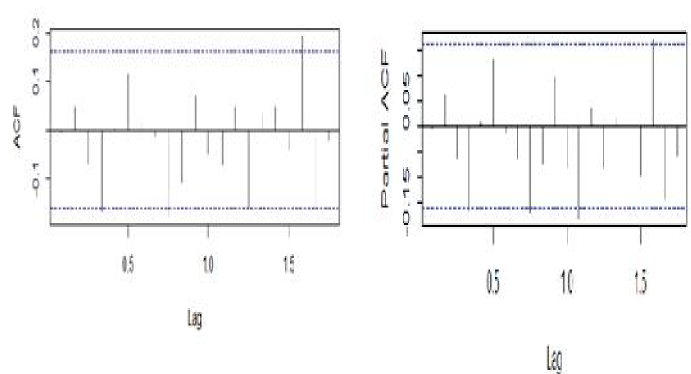

Figure 5: ACF and PACF for Intervention model residuals

5 Discussion

The impact of the Exemption Fee Delivery and Free Maternal Healthcare policy could best be fitted to a simple step function with Zero-order decay. Nonetheless, the Exemption fee delivery demonstrated a delayed abrupt nature of impact on the monthly delivery series. Free Healthcare policy exhibited a sudden permanent impact on the monthly delivery series The results show that Exemption Fee Delivery policy showed a non-significant additional increase of 9 assisted delivery in the hospital. Thus the policy could not significantly attract enough pregnant women to seek professional medical assistance at the hospital. This could probably be due to the little payment associated with the policy. The Free Maternal Health Care policy significantly shot-up the number of assisted delivery at the hospital by approximately 60 additional childbirth. Results from the estimated intervention model confirms results obtain by Omane-Adjepong et. al (2012) at Mampong Government Hospital where, EFDP showed an insignificant change of approximately 9 and a significant additional enrolment of 90 women at the hospital when FMHCP was introduced. Agar and Noemi(2010), also concluded on greater utilization of health service by pregnant women since the implementation of FMHCP. According to Ameyaw(2010), maternal mortality in the New Juaben municipality of Ghana has decrease since the introduction of the FMHCP as more women get assistance during childbirth.

6 Conclusion

These findings clearly shows that the free maternal care programme had significantly increased the monthly number of pregnant women who seek assisted delivery. This confirms the assertion that financial factor is a barrier to assisted delivery and these policies had contributed in reducing the barrier.

Acknowledgement

We wish to express our profound appreciation to workers at Bio-Statistics Department of the Obstetrics & Gynaecology directorate at Kwame Nkrumah University of Science and Technology Hospital, kumasi for the data for this study.

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