Intervention analysis of serious crimes in the eastern region of Ghana

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ABSTRACT

This research was done within the framework of intervention time series analysis to assess the nature and impact of the establishment and operations of community policing in communities in Ghana. In line with this objective, a secondary data made up of monthly serious crimes from 2000 to 2011 were obtained from Regional Criminal Investigations Department (CID), Eastern Regional Command of Ghana Police Service.

An autoregressive integrated moving average, (ARIMA (1,1,0)) models were constructed to analyse the pre and post intervention of serious crimes respectively. Based on the ARIMA(1,1,0) model for the pre-intervention series, a full intervention model was obtained. The intervention strategy was found to have reduced serious crime by 16 cases per month. The reduction was abrupt but temporal and statistically significant at 5% level. However, the statistically insignificant rate of decay (δ) of 0.0369 at 5% level resulted in the temporal effect of the intervention. The overall intervention model is found to be statistically significant at 5% level.

Keywords: ARIMA, Serious Crime, Intervention analysis, Pre-intervention, Post-intervention.

Introduction

The Criminal Code of Ghana (Act 2960), defines crime to include both the act (*actusriea*) and the intent to commit the act (*mensrea*). Originally the Latin word *crīmen* meant "charge" or "cry of distress", which meant that crimes can have devastating and disastrous effects on the victims, community and the nation at large. This therefore calls for a policy intervention to deal with crimes of all forms in societies. One of such policy intervention put in place to help address the issues of crime in Ghanaian communities is the establishment of the Community Policing Unit (CPU) in June 2002 as a unit of the Ghana Police Service to collaborate with members of the communities in dealing with serious crime (SC) through effective communication. The implementation of the community policing in the community took effect in January 2003. After about one year of effective operation, the CPU experienced challenges and subsequent loss of focus.

In a developing country like Ghana, there is an information gap on the extent to which SC can be controlled and whether existing strategies are effectively curbing SC. Even in situations where some successes have been made, the extent and state of the impact on such communities have not been well investigated and understood. Box and Tiao, (1975) introduced intervention time series and its analysis one of the methods for assessing the impact of a special event similar to CPU. However, to best of our knowledge, enough has not been done on SC intervention analysis in Ghana. Although Appiahene-Gyamfi (2002), investigated trends and patterns of robbery series in Ghana, knowledge about the effect of intervention is limited.

This paper attempts to investigate SC prevention intervention on the SC series spanning the years 2000 to 2011 in the Eastern region of Ghana. We interested the pre-intervention SC series from January 2000 to December 2002 and the effect of the intervention on the series from January 2003 onwards. This will aid in the validation of the community policing unit's operation and performance.

Methodology

Data Source

A secondary data made up of monthly SC categories namely; murder, rape, defilement, robbery and the use and possession of drugs (cocaine, heroine, Indian hemp) from January 2000 to December 2011 in the eastern region of Ghana were collected from the Regional CID unit, Eastern Regional Command of Ghana Police Service. These were grouped as monthly SC data.

Methods

Analyses were performed using R. Exploratory data analyses were conducted to investigate patterns, trends and checking of assumption of the time series. ARIMA approach with intervention, similar to Girard (2000), Min *et al.* (2010), Chung, *et al.* (2009), Yaacob et al. (2011) and Zambon *et al.* (2007), was extensively applied to identify the state of SC in the region. The three main iterative processes of model identification and model selection; parameter estimation; and model adequacy checking were done.

An ARIMA (1, 1, 0) error process was modeled for the pre-intervention series based on which the full intervention model was obtained. Portmanteau test, (Box and Pierce, 1970), coupled with the analysis of the residual plots were used to make conclusions about the overall intervention model. The Kwiatkowski-Phillips-Schmidt-Shin (KPSS) and Philips-Perron were used to test for level of stationarity against an alternative of unit root. For all analyses P-value less than 0.05 was considered to be statistically significant.

Data Analysis and Results

Exploratory Data Analysis

Figure 1 is the SC series plot of the data. From the series the SC in Eastern Region of Ghana varied from year to year as well as from month to month with no systematically visible pattern, structural breaks, outliers, and no identifiable trend components. The SC occurrences were fairly high between the years 2000 to 2002 but saw a significant decline in 2003 from nineteen(19) to one (1) and remained fairly constant in the range of one (1) and eight (8) until 2004 which recorded a sharp spike. The quick decline in 2003 is attributed to the intervention. Monthly SC in the region was generally very low between the years 2005 to 2007 with only a few significant spikes (approximately four (4)). The SC further showed up and down movements between 2008 and 2011.

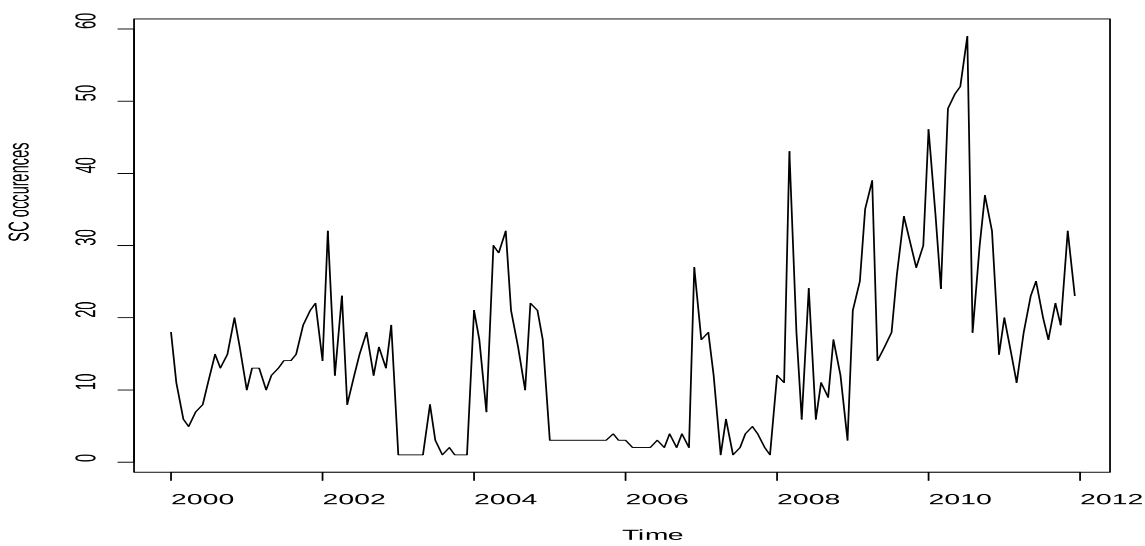

Figure 1: Time Series Graph of SC from 2000 - 2011

Model Formulation and Implementation
An intervention indicator function is formulated as,

$$I_t = \begin{cases} 1 & t \geq 2003 \\ 0, & otherwise \end{cases} \qquad (1)$$

where t is the time and I_t is the intervention indicator. If we consider the form of the pre- intervention model as an ARIMA noise model,

$$N_t = \frac{\theta(L)}{\varphi(L)}\varepsilon_t \qquad (2a)$$

where $\theta(L)$ is forward operator and $\varphi(L)$ is a back shift operator then from Chung *et al.* (2009) the full intervention event is given by;

$$Y_t = c + f(w,\delta)I_t + \frac{\theta(L)}{\varphi(L)}\varepsilon_t \qquad (2b)$$

$$Y_t = c + f(w,\delta)I_t + N_t \qquad (2c)$$

where c is a constant, $f(w,\delta)$ is the resultant impulse real valued function during intervention period, Y_t is the level of change with respect to gains or losses made in the value of reduction.

Visual Analysis of SC series and Models
Based on the visual analysis of the SC plot of Figure 1, a sharp drop is observed at year 2003 but the span of the drop is up to about the end of year 2004. The span is not up a year cycle and hence $f(w,\delta)$ is of the form $\frac{w_0}{(1-\delta\, L)}$ and equation (2) reduces to a first order decay function given by

$$Y_t = c + \frac{w_0}{(1-\delta\, L)}I_t + N_t \qquad (3),$$

where w_0 translates the current (0 lag) into Y_t and δ specifies first order dynamic decay. If $\delta = 0$ then $1 - \delta L = 1$ and equation (3) reduces to simple step function with a zero-order decay given by

$$Y_t = c + w_0 I_t + N_t \qquad (4).$$

On the other hand if $w_0 = 0$ then equation (3) reduces to the ARIMA noise model with a constant

$$Y_t = c + N_t$$

For integrated series, the long term behavior of the effect (from equation (3)) is given by

$$\lim_{t\to\infty} Y_t = \frac{w_0}{1-\delta}.$$

Parameter Estimation for Pre- intervention SC
The KPSS test, p-value of 0.100 greater than 0.05, indicates that there is a level of stationarity in the SC. Philips-Peron test, p-value of 0.01, shows that there is no unit root at 5% level of significance level. There is a slow decay in the ACF with single negative significant spike around the PACF which displays a sharp cutoff at lag 1.

For the differenced pre-intervention SC, the partial autocorrelation for lag 1 is significantly different from zero . The other partial autocorrelations have small corresponding t-statistics. This pattern is typical to an autoregressive (AR) process of order one. The identified order of the model is therefore ARIMA (1,1,0).

As shown in Table 1 below, the estimate of the ARIMA(1,1,0) coefficient (ϕ_1) of -0.6567 is found to be statistically significant.

Table 1: Parameter Estimates for ARIMA (1,1,0) model

Coefficients	Estimate	Std. Error	t-value	P-Value
Ar1	-0.6567	0.1267	-5.1831	0.0000

Estimation and diagnostic checks for the full intervention model

The ARIMA (1,1,0) model of the pre-intervention SC is now carried out together with the intervention function , I_t , to obtain the full intervention model and the change in SC levels . The results of the estimated parameters of the full intervention model of equation (3) are shown in Table 2 below.

Table 2: Parameter Estimates for hypothesized Intervention model

Coefficients	Estimate	Std. Error	t-value	P-Value
AR(1)	-0.3375	0.0789	-4.2776	0.0000
T1-AR(1) (δ.)	0.0369	0.5197	0.0710	0.4717
T1-MA (w_0)	-15.9918	8.5433	-1.8719	0.0316

The T1-MA(w_0) and T1-AR(1)($_c$) denote the estimates of intervention event (CPU) and decay or reduction event respectively. From Table 2, the estimated parameter for the AR(1) significantly differ from zero. The estimated intervention event parameter is -15.9918 and is significant. The estimated decay or reduction component is however not statistically significant. Therefore the estimated ARIMA model is given by,

$$Y_t^* = -0.3375 Y_{t-1}^* + \varepsilon_t \qquad (5)$$

where $Y_t^* = N_t - N_{t-1}$ is the first difference of SC, consequently, $\theta(L)$=1 and $\varphi(L) = 1 + 0.3375L$.

Thus equation (5) is related to equation (2b). This implies the estimated full intervention model is

$$Y_t = -15.9918 I_t + (1 + 0.3375L)^{-1} \varepsilon_t \qquad (6)$$

which is obtained from equation (3)

Diagnostic checks for the full intervention model

To check for adequacy, we examined the plots of the full intervention model and the SC series as shown in Figure 2. The identified model is adequate because it mimics with the SC series.

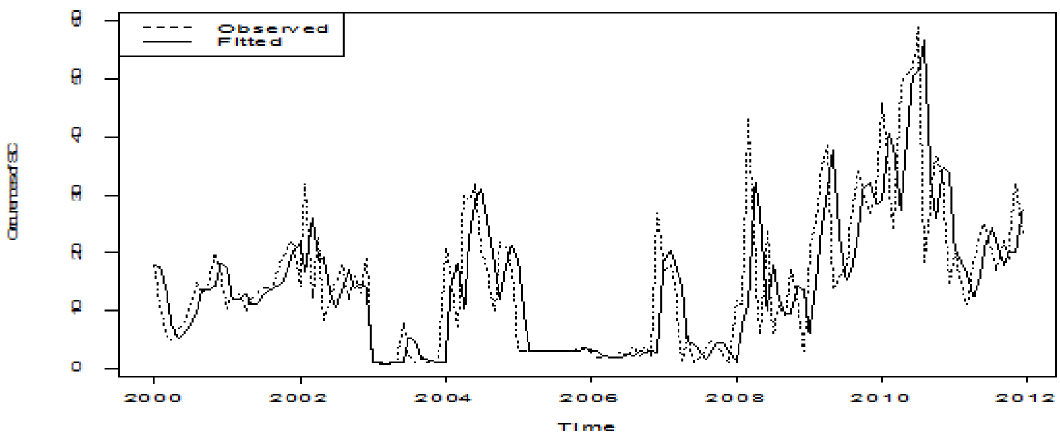

Figure 2: Graph of the fitted intervention verses the observed series

The autocorrelations and the randomness of the residuals were examined using the ACF plot and Ljung-Box test respectively. From table 3, the Ljung-Box test of randomness for the residuals from the full intervention model indicates that the residuals are random at 5 % level of significance (p-value=0.4135). The residuals were found to be uncorrelated. Hence the full intervention model for the SC is adequate.

Table 3: Ljung-Box Test for the Full Intervention model

Test type	Chi-square (χ^2)	df	P-value
Ljung-Box	0.6687	1	0.4135

Discussion

The drop in SC as observed from the visual analysis of Figure 1 was confirmed by the parameter estimate in Table 2, to be w_0 = -15.9918. This drop occurred in 2003 when there were effective CPU activities. The decay parameter δ =0.0369 being insignificant shows that the effect of intervention was temporal and it lasted for about a year (January 2003 to about December 2003). After this date the CPU experienced challenges and loss of focus.

The full model was found to be $Y_t = -15.9918 I_t + (1 + 0.3375L)^{-1} \varepsilon_t$

with pre-intervention part modeleled by $Y_t^* = -0.3375 Y_{t-1}^* + \varepsilon_t$

The full intervention model was confirmed to be adequate since it mimics the original data as was shown in Figure 2.

According to Ghana Statistical Service (2010), Ghanaians have confidence (67%) in reporting crime to the police. Taking into consideration the extent of the monthly drop of 16 cases of SC through the intervention of the CPU, it is assured that the Ghanaian society stands to gain socially if the CPU is reorganized so that people will have increased access to the police in order to facilitate information exchange for prevention of SC.

Conclusion

This is the first study on crime intervention in Ghana and we have shown that the introduction of CPU in Ghana had tremendous impact on SC reduction during the short period it was effectively implemented. The movement of the SC series outside the effective intervention period (the year 2003) shows the ineffectiveness of the Ghana police service in dealing with SC with the traditional reactive policing**.** The reorganization of the of the CPU could be the starting point of innovative and proactive measures to combat SC

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APPENDIX

Appendix I: Monthly Crime statistics in the Eastern Region of Ghana from 2000-2011

	YEAR											
MONTH	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**
January	18	10	14	1	21	3	3	17	12	21	46	20
February	11	13	32	1	17	3	2	18	11	25	34	15
March	6	13	12	1	7	3	2	12	43	35	24	11
April	5	10	23	1	30	3	2	1	18	39	49	18
May	7	12	8	1	29	3	2	6	6	14	51	23
June	8	13	12	8	32	3	3	1	24	16	52	25
July	11	14	15	3	21	3	2	2	6	18	59	20
August	15	14	18	1	16	3	4	4	11	26	18	17
September	13	15	12	2	10	3	2	5	9	34	30	22
October	15	19	16	1	22	3	4	4	17	31	37	19
November	20	21	13	1	21	4	2	2	12	27	32	32
December	16	22	19	1	17	3	27	1	3	30	15	23

Source: Regional CID Unit, Eastern Regional Command of Ghana Police Service (February, 2012)

Appendix II: Code

```
#Reading data in to R
dd=read.table("C:/Documents and Settings/Administrator/Desktop/dars.txt",header=F)
dds=ts(dd,start=2000,freq=12)

# Creating intervention Indicator
ind=rep(0,length(dds[time(dds)<2003]))
length(ind)
ind1=rep(1,length(dds[time(dds)>=2003]))
length(ind1)
indd=c(ind,ind1)
# fitting the Intervention Model
fit=arimax(dds,order=c(1,1,0),xtransf=indd,transfer=list(c(1,0)))# fit without drift
# Residual Analysis
tsdiag(fit$res)
# Code for the plots
plot.ts(dds,ylab="Series")# SC plots
plot(dds,lty=2,ylab="Occurences of SC")
lines(ts(fitted(fit),start=2000,freq=12))
legend("topleft",c("Observed","Fitted"),lty=c(2,1))
```