SAZONAL FORECAST MODEL AND OTHER DETERMINANT ASPECTS CONCERNING THE OCURRENCE OF LETHAL VIOLENT CRIMES IN PERNAMBUCO

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ABSTRACT

The purpose of this article was to find the subjacent factors connected with the behavior of the rate of homicides in Pernambuco throughout the time. The study began with the selection of an appropriate data source to guarantee an acceptable balance between precision and update. In addition, among the possible kinds of murders, only homicides were analyzed because they represented a class far more frequent than other types of lethal violent crimes in the researched area. The investigation proceeded with the visualization of stratified plots of the monthly and daily rate of homicides to understand the effects of each category over this dependent variable. Considering again the whole sample, a Seasonal Multiplicative ARIMA (SARIMA) model was adjusted to the rate of homicides per month, allowing to forecast the evolution of this time series in subsequent periods.

KEYWORDS. Violence. Pernambuco. Time Series.

Main area. AdP. EST.

1. Introduction

Violent behavior is a common human characteristic, at least for some of us, which brings impacts in everyone's life. Violence makes people change habits: not staying out until late night, not carrying valuable belongings in the streets, reducing leisure time in public places, just as few examples. Expressive rate of deaths causes losses in human capital that decrease productivity. The result may be even worse when the percentage of youth homicides is taken into account.

Violence also leads to additional costs to the society, since its effects in public and private spheres can decrease the quality of life. According to Cerqueira et al. (2007), the money spent in public systems to treat the victims of violence and the investment in social security system due to pensions and retirements caused by violence are government extra expenses toward dealing with crime consequences. In addition, people may invest more in private security and self protection against crimes, like bulletproof vehicles, fences and cameras. And when they inevitably become victims of crimes, then more money will be possibly allocated in juridical causes.

Crimes costs represent around US$ 2.1 trillion of annual income worldwide, which is 3.6% of the global Gross Domestic Product (UNODC, 2011). Crime exists because for some individuals the illegal behavior is more profitable than a legal job, even when he perceives the chances of arrest in case of conviction. More specifically, violent crimes are penal infractions caused by the use of intentional force or coercion against a person, not necessarily resulting in death. The Brazilian classification of 'Crimes Violentos Letais e Intencionais' (CVLI) are types of lethal violent crimes where the offenders also have the purpose to kill their victims, such as intentional homicide, robbery followed by death and injury followed by death (MINISTÉRIO DA JUSTIÇA, 2006)

In thirty years, Brazil exceeded one million of murder victims, while Angola, in 27 years of civil war (UNITA) had approximately 550,000 deaths (WAISELFISZ, 2012). Brazil has the third higher homicide rate in Latin America, reaching 22.7 homicides per 100 thousand inhabitants, which corresponds to an absolute number of 43,909 in 2009. Venezuela is settled in the first position of the rank with 49 homicides per 100 thousands inhabitants, while Colombia occupies the second place with a rate of 33.4. (UNODC, 2011).

Since 2003, Brazil has reduced its own numbers of homicides. Despite the Northeast Region of Brazil has not presented the same behavior – with Alagoas leading the homicide rate in Brazil in 2010, 66.8, according to preliminary DATASUS information taking from Waiselfisz (2012), Pernambuco presented a decrease in the CVLI numbers since 2008: approximately 12% in 2009 and 13% in 2010.

In 2007 the government of Pernambuco started the 'Pacto pela Vida' Program, with the objective to take the State out of the first position in the national violence ranking. The goal was to reduce in 12% the yearly CVLI mortality rate. To proove this, the 'Secretaria de Defesa Social de Pernambuco' (SDS/PE), the social security office in Pernambuco responsible for security matters in the state, monthly and quarterly publicizes the CVLI numbers in the its website.

The motivations behind violent crimes are more related to social interaction issues than to economical factors. So social and psychology sciences try to understand the reasons that make people commit a homicide. In the other hand, some researchers are creating algorithms to predict where criminals will strike next (Corcoran et al., 2003; Weisburd et al., 2011; Lum et al., 2011). With the great volume of information a historical database usually provides, several works have been developing forecast models, like the recent studies of McCall et al. (2011), for the United States, and Resnushe et al. (2012), for Satara District in India.

In Pernambuco, it is also of great importance studying the dynamical evolution of violent crimes, as well as the spatial correlations and behavioral factors related to their occurrence, in order to reduce them further. In this article a forecast model is presented to indicate how temporal patterns can predict violence incidence in Pernambuco. For that purpose, a

SARIMA model was developed for the estimated rate of homicides during the period from January 2007 to March 2012.

2. Violence Causes and Effects in Brazil

The social inequality, the political context and the relative poorness can explain the high homicide rates (BARBOSA, 2011). According to the Mortality Information System of Health Vigilance Office in the Brazilian Health Ministry (SIM/SVS/MS), the homicide numbers in Brazil has achieved 47,707 victims in 2007 and 50,000 victims in 2009, which means almost six homicides per hour. In Pernambuco, the homicide rate per 100 thousand inhabitants was 51.7 in 1997. In 2007, there was a raise of 7% in the index (55.6 per 100 thousand inhabitants) in ten years (WAISELFISZ, 2012).

In Brazil, the public security area is not a responsibility of municipalities. It is totally managed by Federal and State governments. The public security actions are planned without community and municipal government involvement, where the criminality consequences are perceived and where they face the social and economical costs about this problem. The mayors have no power to manage the police who work in their communities and still end up bearing extra expenses (BOSELLI, 2008). Studies about crime evolution and other factors that contribute with the violence, can help municipalities to work on strategic planning to combat this issue.

Unemployment and poorness are associated as fundamental causes to violence. Lima *et al.* (2005) showed a negative association between illiteracy rate and poorness rate with the homicide rate of municipals in Pernambuco among 1995 and 1998. It is not clear how income and unemployment affects criminality. The traditional theory says the higher the income and lower the unemployment, the lower is the criminality. But other authors affirm that since the prison reduces the perspective of employment and income, the criminals reduce their illegal activities (SOARES, 2008).

The homicide rate is also related with populational growth in the metropolitan regions, which associated with other factors, like disorganized urbanization, higher population density, concentration of shanty-towns; bad income distribution and deep social inequality, create a scenario of social exclusion (BARBOSA, 2011; BOSELLI, 2008; DE SOUZA & LIMA, 2006).

Some specialists affirm that the drug traffic and the existence of extermination groups are responsible for a considerable part of the criminal activities (LIMA et al. 2005A; 2005B; RATTON et al., 2011). However, Nóbrega Jr. (2010) advises how fragile can be a relationship between drug traffic and homicides without taking into consideration other aspects, as a growth in economical activities.

The availability of firearms is an important variable to determine the range of the crime. A tighter control on firearms through legislation (disarmament statute) and the disarmament campaigns might help the reduction in the crime numbers.

The Health Ministry analyzed the results in the cities where the police force or the investments had raised. In the municipals that received financial resources there was an average reduction in the mortality rate due to aggression from 2000 to 2005 of 2.94 per 100 inhabitants, but it was not a significant reduction. While in the municipals with a raise in the security, the mortality rate due to aggression from 2000 to 2005 presented a significant reduction of 3.83 per 100 thousand inhabitants. It is important to remind that hiring polices without the proper training and without improving their means of work will not give the expected result (NÓBREGA, 2011).

In the same period of the program 'Pacto pela Vida', the government effort that begun in 2007 to lower the violent crimes in the Pernambuco, there were other initiatives that must be considered. Both programs 'Benefício de Prestação Continuada' (BPC) and 'Programa Bolsa Família' (PBF) were responsible for the reduction in the inequality and the improvement of the life conditions. This fact had a direct effect in the criminality indexes, at least between 2002 and 2008, when the poverty decreased expressively (NÓBREGA, 2011). A remarkable breaking in 2003 was signaled in the homicide rate growth, as indicated in figure 1, and a lot of factors seem to explain this: the Disarmament Statute, the planning of federal resources and different strategies of some state governments.

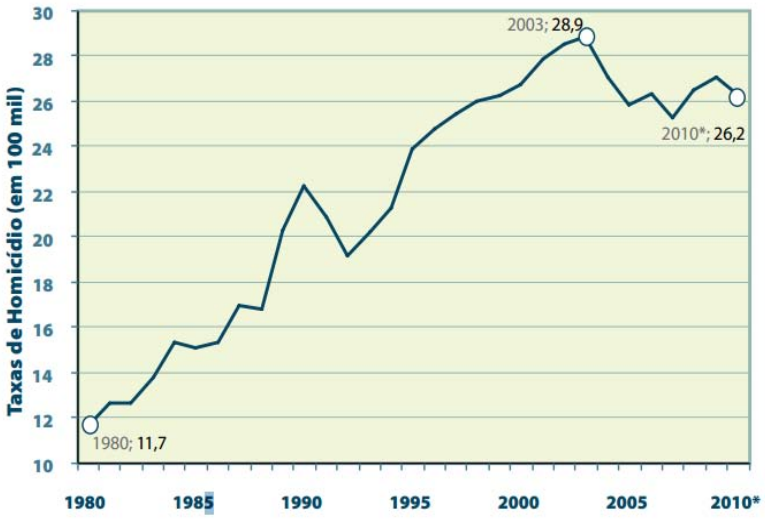

Figure 1: Evolution in the rate of homicides. Brazil, 1980/2010*
Source: Waiselfisz (2012) SIM/SVS/MS *2010: Preliminary data

3. Selection of the Data Source

One of the mainly problem in the scientific studies about mortality in Brazil is the fact that there is no uniformity of the databases. SDS/PE has been doing efforts to keep a database that follows the standard of the National Public Security Office (SENASP). Created in 2003, the Police Information System (INFOPOL), controlled by SDS/PE, feeds the database with information of the Diary Reports of Necropsy in the Legal Medicine Institute (Caruaru, Petrolina and Recife) and the Civil Policy Coordination Diary Report (UNICODPLAN/PCPE).

There are no qualified personnel in Civil Police to register every criminal event, although not all intentional death is classified as homicide like, for example, supposedly police confrontation with civilians, what would demonstrates an accountability failure of the state security managers.

The *Mortality Information Subsystem in Health Unique System Database* (DATASUS/SIM) has homogeneity in all states of Brazil according to the international classification of World Health Organization (WHO) diseases. The database information are the certificate of death filled by physicians and data collected by notary's office. The SIM presents a temporal serie since 1996 until 2010.

There is a methodological difference in the data collection systematic between DATASUS and INFOPOL. Due to the low quality of what was recorded, INFOPOL has no information about the place of occurrence, but does annotate the homicide place of register. On the other hand, DATASUS situates the occurrence according to the victims' place of residence and a statement of the place of death. It can sometimes happen that someone dies in a distinct city from where she/he lives, besides receiving a certificate of death in a third city.

Since the aim of this article is to find a forecast model for violent crimes committed in Pernambuco, the most updated database was chosen. So despite other authors have concluded that the DATASUS/SIM is the most cohesive database for Pernambuco, it would not be so useful for a forecast model since the data is not so recent to adjust and extrapolate the indicators to future periods.

4. Homicides in Pernambuco

Waiselfisz (2012) divides Pernambuco homicide scenario in four periods: (I) Pernambuco rates go along with the national growth; (II) there is an increase above the national average rate (7.9% per year in Pernambuco against 3.9% per year in Brazil), when the State reaches the first place in a national ranking from 1991 to 2001; (III) tendency to stagnation of the violence raise, where the descending slope follows the national rhythm; and (IV) there is a sharp

decline in Pernambuco homicide rate, while the national rates are raising up very slowly. The first two scenarios have an increasing homicide rate and both last until 2003. The latter two periods point out a soft decline in the homicide rates and after 2007 a more intense decline with an approximation between the metropolitan region rates and the rates of the inner part of the State. That is why only the last two periods are studied in this paper. Since the behavior in the homicide rates is different, with a decline of the rates, it will be robust for a forecast model.

All data used in this article could be freely downloaded from the site of SDS/PE. The information was organized by victims of violent crimes identified in its jurisdiction. Other variables include the date of death, the name and the age of the victim, the city where the crime happened, the type of crime (homicide/robbery followed by death/corporal injury followed by death/other) and the object used to commit the crime (firearm/sharp weapon/other). Because approximately 96.3% of the crimes were qualified as homicides, the analysis concentrated most on this category.

The monthly rates were derived simply by adding all daily rates for each month. The first and the last months in the series, respectively April 2007 and December 2011, had therefore to be discarded, because the missing days in both months could produce distortion in the final results.

As to eliminate the influence of population increase, what could artificially induce undesirable trends in the studied series, rates of homicides (*per capita*) were computed and used instead of the original values. The number of inhabitants in Pernambuco, given in a yearly base (IBGE, 2012), was attributed to the center of the respective year, more specifically in the first day of every month of July. The estimated population growth was then smoothed by a centered moving average for a period of 200 days, taking the correspondent observation, as well as 100 values after and 99 before it, applied to the interpolation of the yearly number of citizens. This transformation intended to break the abrupt change in the vertices, what could make the time series assimilate the same pattern. At the end, a linear extension was assumed to reach the days in both extremes of all the interval. The final result of these operations can be observed in Figure 2.

Figure 3 introduces an interval plot of the rate of homicides stratified by the day of the week. The dependent variable was obtained by taking the mean of all rates of the same type of day. The graph showed statistically significant differences from their expected values comparison (Kruskal-Wallis Test). The center of the week, basically Tuesdays to Thursdays, was as a relatively peaceful period, in terms of having the lowest registered number of homicides occurrence, while Sundays were identified as the most violent day, immediately followed by Saturdays, reaching a level that more than doubles the minimum expected rate.

To compare the rate of homicides per month in terms of the geographical region of the victims' death, the sample was divided in two groups, depending whether the place of murder was located in the Metropolitan Region of Recife (RMR), the capital city of Pernambuco, or the place situated in the inner part of the State. The resulting graph is shown in Figure 4, confirming a slightly higher level in the RMR. When the rates of homicides are analyzed in respect to the object used as a crime weapon, it is possible to perceive some difference, being the firearms much more common than the sharp ones as a murder weapon, as represented in Figure 5.

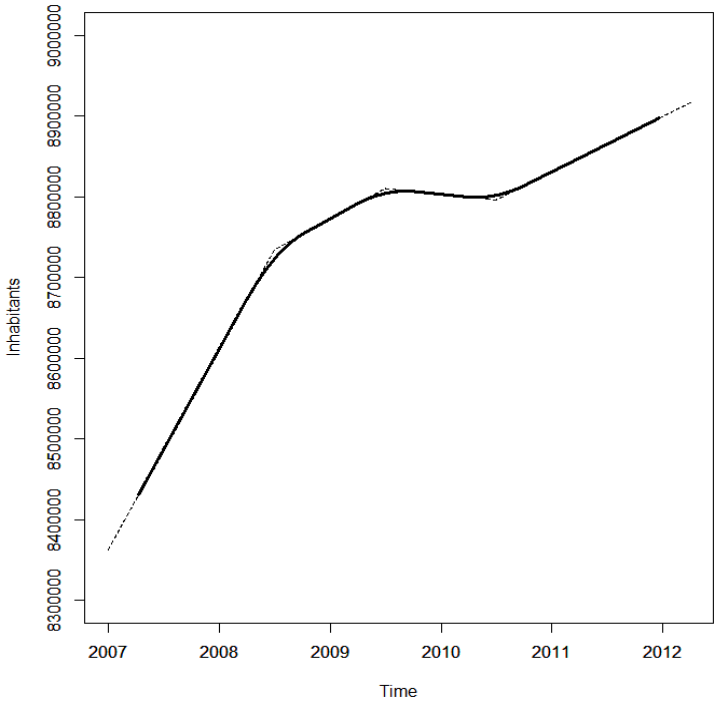

Figure 2: Estimated population growth in Pernambuco

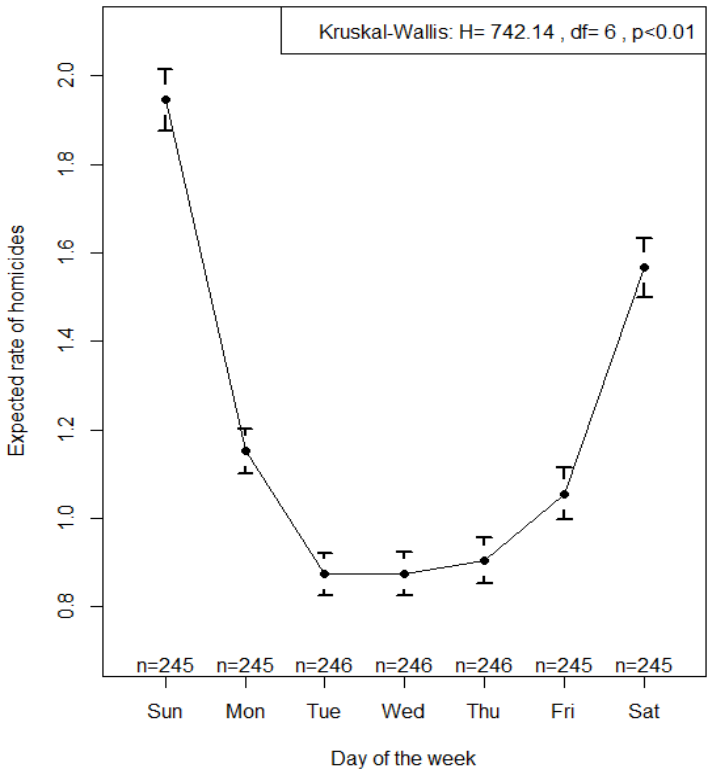

Figure 3: Expected rate of homicides by the day of the week

Figure 4: Monthly rate of homicides by geographical region

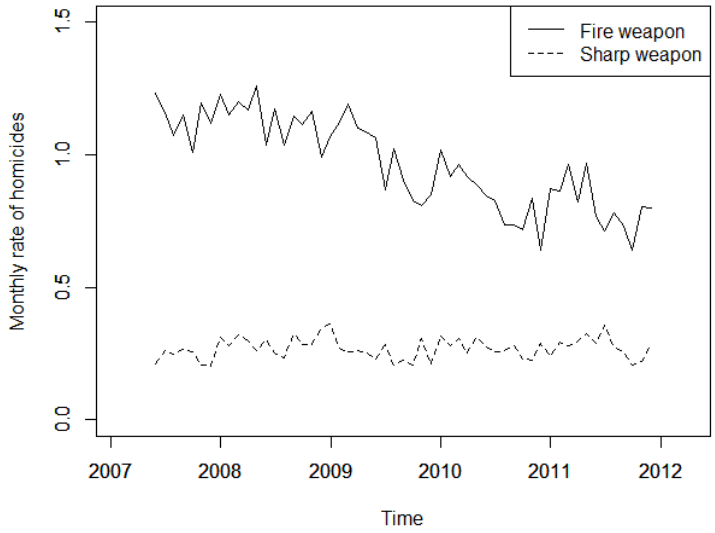

Figure 5: Monthly rate of homicides by geographical region

Considering the rate of homicides per month plotted in Figure 2, a model to forecast the behavior of this measure would allow to anticipate the level of the time series in subsequent times. An ARIMA model was developed, with the purpose of extrapolating the evolution of the number of homicides. After searching for the best model for the time series among the classical Box & Jenkins' ARIMA, it was found to be an ARIMA(1,1,0). However, a persistent correlation observed in lag 12 of the Partial Autocorrelation Function (PACF) indicated the presence of a seasonal component, which could not be handled by this class of models. Such aspect gave reason to an investigation for a Seasonal Multiplicative ARIMA (SARIMA), which consists of a stochastic predictor that assumes seasonal lags, multiple of some predetermined period, which in this case, equals to 12. The result of this new search is briefly described by the following items.

- Model Type: SARIMA $(1,1,0)\times(1,1,0)[12]$.
- Model Coefficients: arima1 = -0.5706 (standard error = 0.1316); sarima1 = -0.7040 (standard error = 0.1033).
- Information Criteria: Log likelihood = -97.14; AIC = 200.28; BIC = 205.5.
- In-sample Error Measures: ME=0.148; RMSE=1.929; MAE=1.357; MPE=0.300; MAPE=3.922; MASE=0.449.

The log likelihood value, Akaike (AIC) and Bayesian (BIC) information criteria were used in the selection of the best SARIMA model, as well as some of the main in-sample error measures, like Mean Error (ME), Root Mean Squared Error (RMSE), Mean Absolute Error (MAE), Mean Percentage Error (MPE), Mean Absolute Percentage Error (MAPE) and Mean Absolute Scaled Error (MASE)

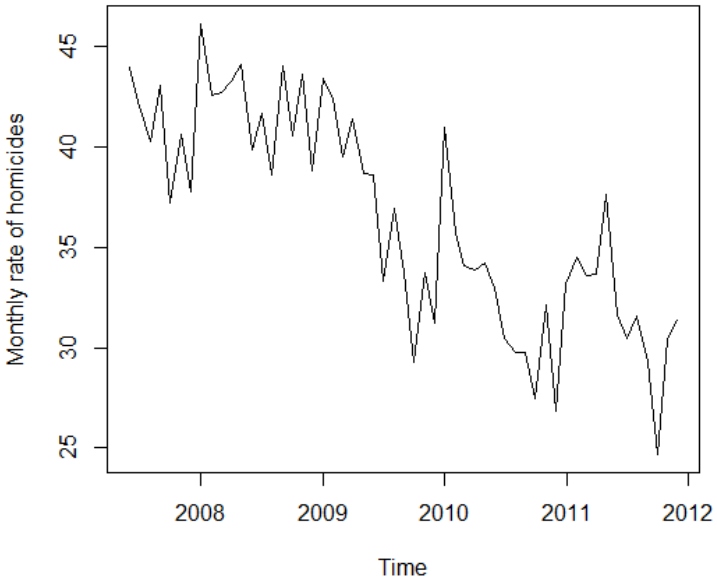

Figure 6: Time series for the monthly rate of homicides in Pernambuco

Figure 7, 8 and 9 present some diagnostic tests conducted to assure the validity of the fitted model. It can be seen that there's no significant correlation left in the ACF of residuals, likewise all the Ljung-Box statistics, that are far above the significance level 0.05, when testing if the data are not independently distributed (alternative hypothesis), which is the same as testing if the residuals have some correlation. Figure 10 also certifies that, based on the normal quantile-quantile plot, as well as on the Shapiro-Wilks, Lilliefors and Anderson-Darling tests, it's acceptable to assume that the residuals from the model are normally distributed.

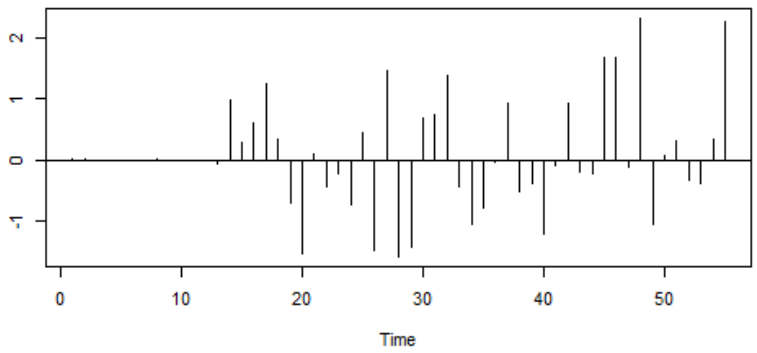

Figure 7: Standardized Residuals

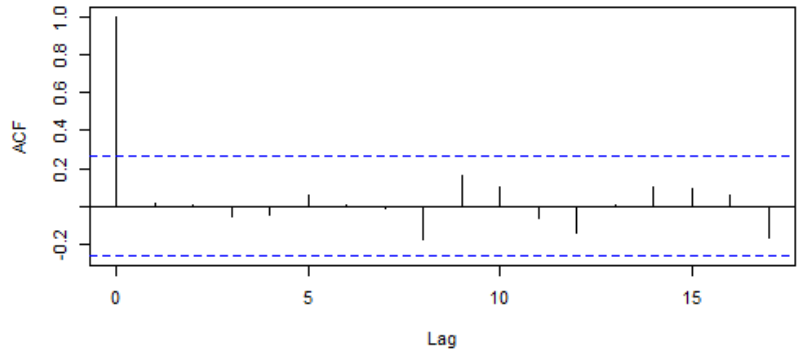

Figure 8: ACF of Residuals

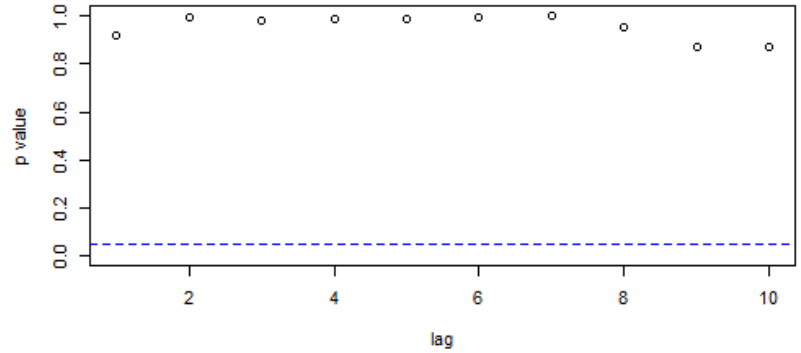

Figure 9: P-values for Ljung-Box statistic

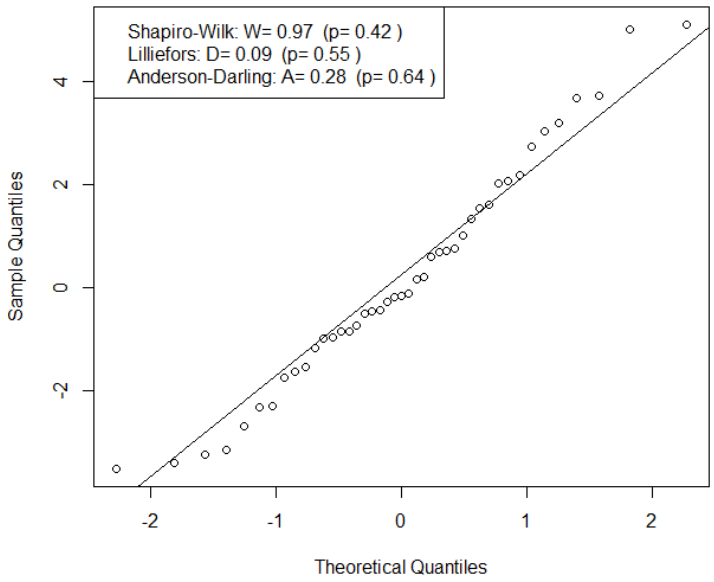

Figure 10: Normality tests for the residuals of the fitted model

In Figure 11, a forecast for the period of one year ahead in the time series, after the last month used to build the model, is totally consistent with the trend and seasonality detected in the precedent months. The 95% confidence interval for the predicted values can be also visualized by the dotted lines.

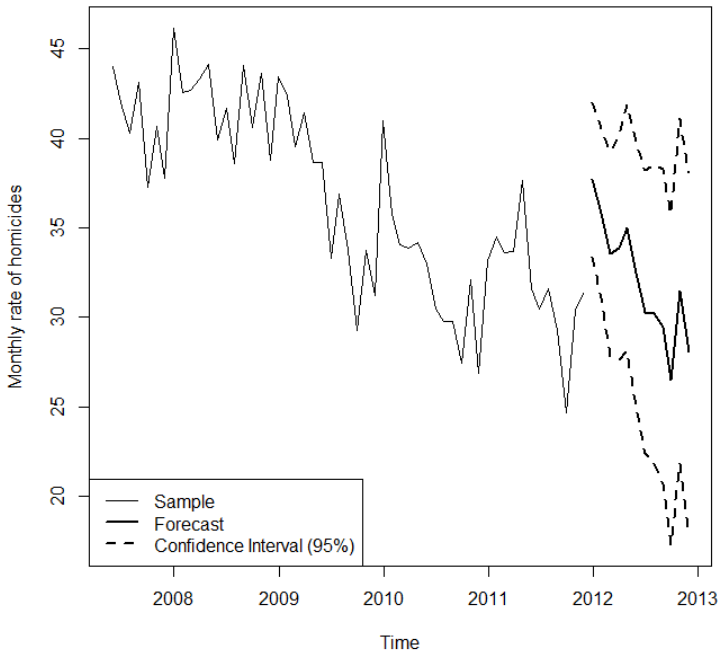

Figure 11: One year forecasted monthly rate of homicides from the fitted model

5. Conclusions

Some of the aspects concerning the occurrence of lethal violent crimes in Pernambuco were pointed out. First of all, an evaluation over the incidence of homicides during the days of the week allowed identifying a significant distinguished behavior, being the weekends often a violent period of time. In addition, it was both concluded that murders detected in the Metropolitan Region of Recife and homicides whose a firearm was the main object used by the criminals to offend their victims occur more frequently in Pernambuco than other possible situations.

Developed to predict future evolution on the rate of homicides, the SARIMA model suggested the presence of seasonal influences with cycles of 12 months. This observation is a clear indication that, for some yet unknown reason, the rate of homicides in Pernambuco may change depending on the month of the year. This oscillation can be a reflex of some calendar event, like festive dates or simply due to periods of intense trade, all of which deserves yet to be thoroughly investigated.

The data source used to get the estimates and models in this article may also be subject to further improvements, especially if the intention is to derive more robust results. INFOPOL limited the sample because only data since the year of 2007 was available at the time of its collection. Datasets that comprehend a greater time interval, like the one provided by DATASUS, could, for example, lead to a better comprehension of the causes surrounding the chosen violence indicators. Moreover, the structure of the database and the procedure to collect the necessary data may also produce adverse effects in the estimates, making it even more difficult to find any relation between the analyses coming from these sources.

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