CHAPTER 15

Homicides and suicides in Cape Town, 1986–1991

15.1 Introduction

In South Africa, as in the USA, gun control is a subject of much public interest and debate. In a project intended to study the apparently increasing tendency for violent crime to involve firearms, Dr L.B. Lerer collected data relating to homicides and suicides from the South African Police mortuary in Salt River, Cape Town. Records relating to most of the homicide and suicide cases occurring in metropolitan Cape Town are kept at this mortuary. The remaining cases are dealt with at the Tygerberg Hospital mortuary. It is believed, however, that the exclusion of the Tygerberg data does not materially affect the conclusions.

The data consist of all the homicide and suicide cases appearing in the deaths registers relating to the six-year period from 1 January 1986 to 31 December 1991. In each such case the information recorded included the date and cause of death. The five (mutually exclusive) categories used for the cause of death were: firearm homicide, nonfirearm homicide, firearm suicide, nonfirearm suicide, and 'legal intervention homicide'. (This last category refers to homicide by members of the police or army in the course of their work. In what follows, the word homicide, if unqualified, means homicide other than that resulting from such legal intervention.) Clearly some of the information recorded in the deaths registers could be inaccurate, e.g. a homicide recorded as a suicide, or a legal intervention homicide recorded as belonging to another category. This has to be borne in mind in drawing conclusions from the data.

15.2 Firearm homicides as a proportion of all homicides, suicides and legal intervention homicides

One question of interest that was examined by means of HMMs was whether there is an upward trend in the proportion of all the deaths recorded that are firearm homicides. This is of course quite distinct from the question of whether there is an upward trend in the *number* of firearm homicides. The latter kind of trend could be caused by an increase in the population exposed to risk of death, without there being any other

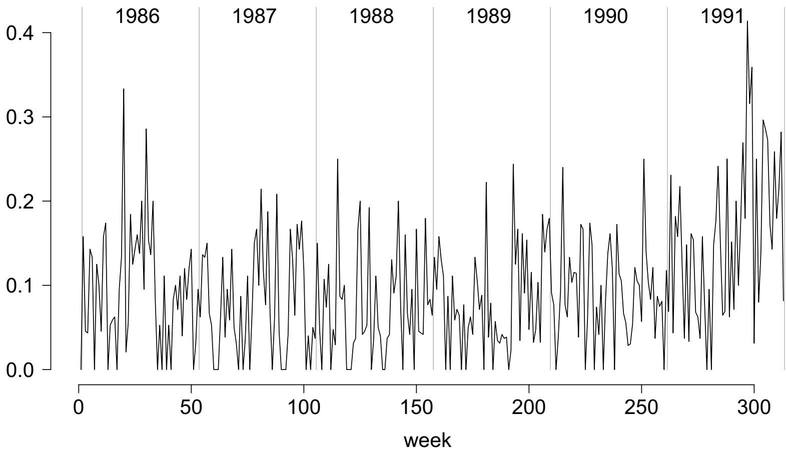

Figure 15.1 *Firearm homicides 1986–1991, as a proportion of all homicides, suicides and legal intervention homicides.*

relevant change. This distinction is important because of the rapid urbanization which has taken place in South Africa and has caused the population in and around Cape Town to increase dramatically.

Four models were fitted to the 313 weekly totals of firearm homicides (given the weekly totals of all the deaths recorded); for a plot of the firearm homicides in each week, as a proportion of all homicides, suicides and legal intervention homicides, see Figure 15.1.

The four models are: a two-state binomial–HMM with constant 'success probabilities' p_1 and p_2; a similar model with a linear time trend (the same for both states) in the logits of those probabilities; a model allowing differing time-trend parameters in the two states; and finally, a model which assumes that the success probabilities are piecewise constant with a single change-point at time 287 — i.e. on 2 July 1991, 26 weeks before the end of the six-year period studied. The time of the change-point was chosen because of the known upsurge of violence in some of the areas adjacent to Cape Town, in the second half of 1991. Much of this violence was associated with the 'taxi wars', a dispute between rival groups of public transport operators.

The models were compared on the basis of AIC and BIC. The results are shown in Table 15.1. Broadly, the conclusion from BIC is that a single (upward) time trend is better than either no trend or two trend parameters, but the model with a change-point is the best of the four. The details of this model are as follows. The underlying Markov chain

Table 15.1 *Comparison of several binomial–HMMs fitted to the weekly counts of firearm homicides, given the weekly counts of all homicides, suicides and legal intervention homicides.*

model with	k	$-l$	AIC	BIC
p_1 and p_2 constant	4	590.258	1188.5	1203.5
one time-trend parameter	5	584.337	1178.7	1197.4
two time-trend parameters	6	579.757	1171.5	1194.0
change-point at time 287	6	573.275	**1158.5**	**1181.0**

has transition probability matrix

$$\begin{pmatrix} 0.658 & 0.342 \\ 0.254 & 0.746 \end{pmatrix}$$

and stationary distribution (0.426, 0.574). The probabilities p_1 and p_2 are given by (0.050, 0.116) for weeks 1–287, and by (0.117, 0.253) for weeks 288–313. From this it appears that the proportion of the deaths that are firearm homicides was substantially greater by the second half of 1991 than it was earlier, and that this change is better accommodated by a discrete shift in the probabilities p_1 and p_2 than by gradual movement with time, at least gradual movement of the kind that we have incorporated into the models with time trend. (In passing, this use of a discrete shift further illustrates the flexibility of HMMs.) One additional model was fitted: a model with change-point at the end of week 214. That week included 2 February 1990, on which day President de Klerk made a speech which is widely regarded as a watershed in South Africa's history. That model yielded a log-likelihood of -579.83, and AIC and BIC values of 1171.67 and 1194.14. Such a model is therefore inferior to the model with the change-point at the end of week 287.

15.3 The number of firearm homicides

In order to model the number (rather than the proportion) of firearm homicides, Poisson–HMMs were also fitted. The weekly counts of firearm homicides are shown in Figure 15.2. There is a marked increase in the level of the series at about week 287 (mid-1991), but another, less distinct, pattern is discernible in the values prior to that date. There seems to be persistence in those periods when the counts are high (e.g. around weeks 25 and 200); runs of relatively calm weeks seem to alternate with runs of increased violence. This observation suggests that a two-state HMM might be an appropriate model.

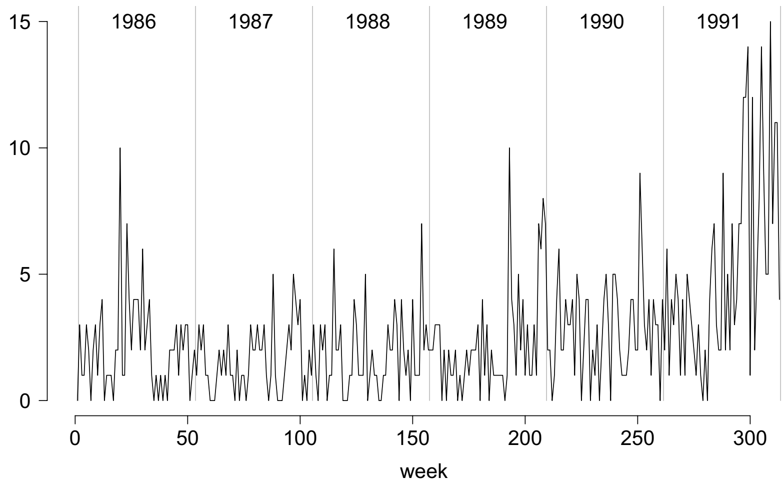

Figure 15.2 *Weekly counts of firearm homicides, 1986–1991.*

Table 15.2 *Comparison of several Poisson–HMMs fitted to weekly counts of firearm homicides.*

model with	k	$-l$	AIC	BIC
λ_1 and λ_2 constant	4	626.637	1261.3	1276.3
loglinear trend	5	606.824	1223.6	1242.4
log-quadratic trend	6	602.273	**1216.5**	**1239.0**
change-point at time 287	6	605.559	1223.1	1245.6

The four models fitted in this case were: a two-state model with constant conditional means λ_1 and λ_2; a similar model with a single linear trend in the logs of those means; a model with a quadratic trend therein; and finally, a model allowing for a change-point at time 287. A comparison of these models is shown in Table 15.2.

The conclusion is that, of the four models, the model with a quadratic trend in the conditional means is best. In detail, that model is as follows. The underlying Markov chain has transition probability matrix given by $\begin{pmatrix} 0.881 & 0.119 \\ 0.416 & 0.584 \end{pmatrix}$ and stationary distribution (0.777, 0.223). The conditional means are given by

$$\log {}_t\lambda_i = 0.4770/1.370 - 0.004858t + 0.00002665t^2,$$

where t is the week number and i the state. The fact that a smooth trend

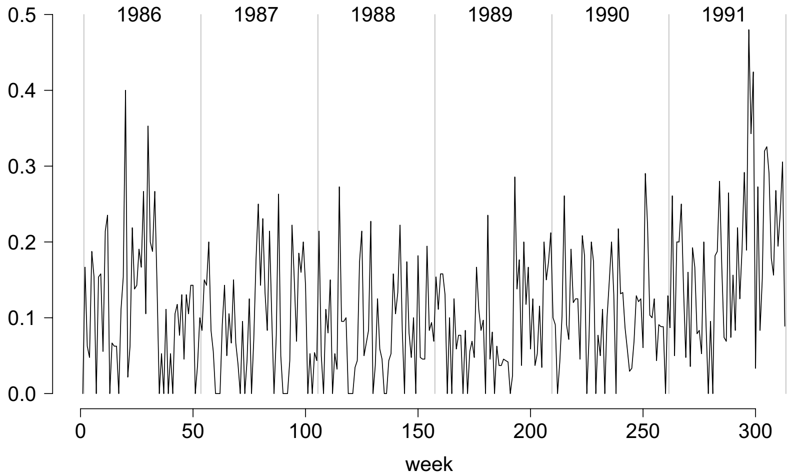

Figure 15.3 *Firearm homicides as a proportion of all homicides, 1986–1991. The week ending on 2 July 1991 is week 287.*

works better here than does a discrete shift may possibly be explained by population increase due to migration, especially towards the end of the six-year period.

15.4 Firearm homicides as a proportion of all homicides, and firearm suicides as a proportion of all suicides

A question of interest that arises from the apparently increased proportion of firearm homicides is whether there is any similar tendency in respect of suicides. Here the most interesting comparison is between firearm homicides as a proportion of all homicides and firearm suicides as a proportion of all suicides. Plots of these two proportions appear as Figures 15.3 and 15.4. Binomial–HMMs of several types were used to model these proportions, and the results are given in Tables 15.3 and 15.4.

The chosen models for these two proportions are as follows. For the firearm homicides the Markov chain has transition probability matrix $\begin{pmatrix} 0.695 & 0.305 \\ 0.283 & 0.717 \end{pmatrix}$ and stationary distribution (0.481, 0.519). The probabilities p_1 and p_2 are given by (0.060, 0.140) for weeks 1–287, and by (0.143, 0.283) for weeks 288–313. The unconditional probability that a homicide involved the use of a firearm is therefore 0.102 before the change-point, and 0.216 thereafter. For the firearm suicides, the transition probability matrix is $\begin{pmatrix} 0.854 & 0.146 \\ 0.117 & 0.883 \end{pmatrix}$, and the stationary distri-

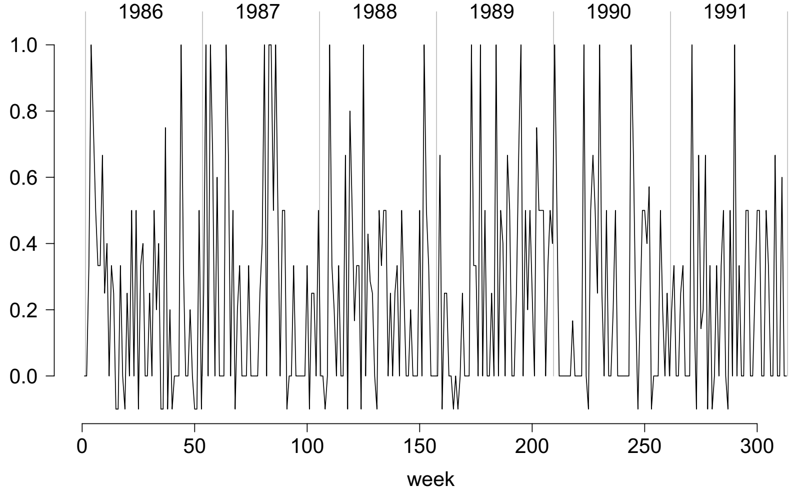

Figure 15.4 *Firearm suicides as a proportion of all suicides, 1986–1991. (Negative values indicate no suicides in that week.)*

Table 15.3 *Comparison of binomial–HMMs for firearm homicides given all homicides.*

model with	k	$-l$	AIC	BIC
p_1 and p_2 constant	4	590.747	1189.5	1204.5
one time-trend parameter	5	585.587	1181.2	1199.9
two time-trend parameters	6	580.779	1173.6	1196.0
change-point at time 287	6	575.037	**1162.1**	**1184.6**

bution is (0.446, 0.554). The probabilities p_1 and p_2 are given by (0.186, 0.333), and the unconditional probability that a suicide involves a firearm is 0.267.

A question worth considering, however, is whether time series models are needed at all for these proportions. Is it not perhaps sufficient to fit a one-state model, i.e. a model which assumes independence of the consecutive observations but is otherwise identical to one of the time series models described above? Models of this type were therefore fitted both to the firearm homicides as a proportion of all homicides, and to the firearm suicides as a proportion of all suicides. The comparisons of models are presented in Tables 15.5 and 15.6, in which the parameter p represents the probability that a death involves a firearm.

The conclusions that may be drawn from these models are as follows.

Table 15.4 *Comparison of binomial–HMMs for firearm suicides given all suicides.*

model with	k	$-l$	AIC	BIC
p_1 and p_2 constant	4	289.929	**587.9**	**602.8**
one time-trend parameter	5	289.224	588.4	607.2
two time-trend parameters	6	288.516	589.0	611.5
change-point at time 287	6	289.212	590.4	612.9

Table 15.5 *Comparison of several 'independence' models for firearm homicides as a proportion of all homicides.*

model with	k	$-l$	AIC	BIC
p constant	1	637.458	1276.9	1280.7
time trend in p	2	617.796	1239.6	1247.1
change-point at time 287	2	590.597	**1185.2**	**1192.7**

For the homicides, the models based on independence are without exception clearly inferior to the corresponding HM time series models. There is sufficient serial dependence present in the proportion of the homicides involving a firearm to render inappropriate any analysis based on an assumption of independence. For the suicides the situation is reversed; the models based on independence are in general superior. There is in this case no convincing evidence of serial dependence, and time series models do not appear to be necessary. The 'best' model based on independence assigns a value of 0.268 (= 223/833) to the probability that a suicide involves the use of a firearm, which is of course quite consistent with the value (0.267) implied by the chosen HMM.

To summarize the conclusions, therefore, we may say that the pro-

Table 15.6 *Comparison of several 'independence' models for firearm suicides as a proportion of all suicides.*

model with	k	$-l$	AIC	BIC
p constant	1	291.166	**584.3**	**588.1**
time trend in p	2	290.275	584.6	592.0
change-point at time 287	2	291.044	586.1	593.6

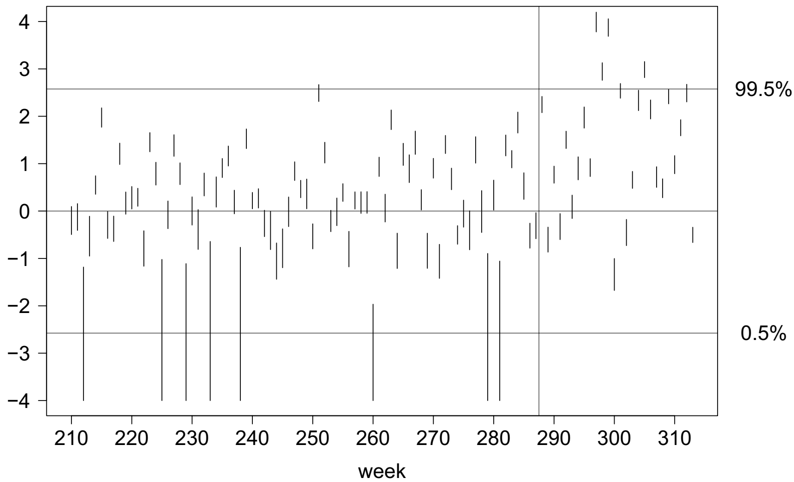

Figure 15.5 *Firearm homicides as a proportion of all homicides: forecast pseudo-residual segments computed from a model for weeks 1–209 only. The vertical line is immediately after week 287.*

portion of homicides that involve firearms does indeed seem to be at a higher level after June 1991, but that there is no evidence of a similar upward shift (or trend) in respect of the proportion of the suicides that involve firearms. There is evidence of serial dependence in the proportion of homicides that involve firearms, but not in the corresponding proportion of suicides.

In view of the finding that the proportion of homicides due to firearms seems to be higher after June 1991, it is interesting to see whether the monitoring technique introduced in Section 6.2.3 would have detected such a change if used over the final two years of the study period. The data for weeks 1–209 only (essentially the first four years, 1986–1989) were used to derive a model with constant probabilities p_1 and p_2 for the weekly numbers of firearm homicides as a proportion of all homicides. For each r from 210 to 313 the conditional distribution (under this model) of X_r given the full history $\mathbf{X}^{(r-1)}$ was then computed, and the extremeness or otherwise of the observation x_r was assessed with the help of a plot of forecast pseudo-residuals, which is shown as Figure 15.5.

The result is clear. Not one of the 78 weeks 210–287 produces a pseudo-residual segment lying outside the bands at 0.5% and 99.5%. Weeks 288–313 are very different, however. Weeks 297, 298, 299 and 305 all produce segments lying entirely above the 99.5% level, and within weeks 288–313 there are none even close to the 0.5% level. We therefore conclude that, although the data for 1990 and the first half of 1991 are reasonably consistent with a model based on the four years 1986–1989, the data for the second half of 1991 are not; after June 1991, firearm homicides are at a higher level, relative to all homicides, than is consistent with the model.

15.5 Proportion in each of the five categories

As a final illustration of the application to these data of HMMs, we describe here two multinomial–HMMs for the weekly totals in each of the five categories of death. These models are of the kind introduced in Section 8.4.1. Each has two states. One model has constant 'success probabilities' and the other allows for a change in these probabilities at time 287. The model without change-point has ten parameters: two to determine the Markov chain, and four independently determined probabilities for each of the two states. The model with change-point has 18 parameters, since there are eight independent success probabilities relevant to the period before the change-point, and eight after. For the model without change-point, $-l$ is 1810.059, and for the model with change-point it is 1775.610. The corresponding AIC and BIC values are 3640.1 and 3677.6 (without change-point), and 3587.2 and 3654.7 (with). The model with the change-point at time 287 is therefore preferred, and we give it in full here. The underlying Markov chain has transition probability matrix

$$\begin{pmatrix} 0.541 & 0.459 \\ 0.097 & 0.903 \end{pmatrix}$$

and stationary distribution (0.174, 0.826).

Table 15.7 displays, for the period up to the change-point and the period thereafter, the probability of each category of death in state 1 and in state 2, and the corresponding unconditional probabilities. The most noticeable difference between the period before the change-point and the period thereafter is the sharp increase in the unconditional probability of category 1 (firearm homicide), with corresponding decreases in all the other categories.

Clearly the above discussion does not attempt to pursue all the questions of interest arising from these data that may be answered by the fitting of HM (or other) time series models. It is felt, however, that the models described, and the conclusions that may be drawn, are sufficiently illustrative of the technique to make clear its utility in such an application.

Table 15.7 *Multinomial–HMM with change-point at time 287. Probabilities associated with each category of death, before and after the change-point.*

Weeks 1–287

	category 1	2	3	4	5
in state 1	0.124	0.665	0.053	0.098	0.059
in state 2	0.081	0.805	0.024	0.074	0.016
unconditional	0.089	0.780	0.029	0.079	0.023

Weeks 288–313

	category 1	2	3	4	5
in state 1	0.352	0.528	0.010	0.075	0.036
in state 2	0.186	0.733	0.019	0.054	0.008
unconditional	0.215	0.697	0.018	0.058	0.013

Categories:
1 firearm homicide
2 nonfirearm homicide
3 firearm suicide
4 nonfirearm suicide
5 legal intervention homicide.