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A new look at an old problem: Finding temporal patterns in homicide series—the Canadian case

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ABSTRACT

It is believed by criminologists that the incidence of crimes committed against persons is highest in the summer. Knowledge about the annual patterns and other temporal behavior of such crimes can help authorities in prevention. The objective of this study is to reveal the temporal behavior of murders in Canada and assess if they are affected by trend-cyclical and/or seasonal influences. The series analyzed comprise the period 1961 to 1980 and are classified according to suspects and victims. Only the quarterly series display a significant seasonal pattern, with the peak occurring in the third quarter. We have also analyzed the relationship between the trend cycle of the murder series and two other variables, namely unemployment rate and rate of growth of the 15-to-44 age group.

RÉSUMÉ

Les criminologistes sont d'avis que le nombre de crimes commis contre la personne est plus élevé l'été. Une telle connaissance des mouvements temporels caractéristiques des séries de crime contre la personne peut contribuer à la prévention de tels crimes. Le but de cette étude est justement de déceler la présence et d'estimer des mouvements temporels tels la saisonnalité et la tendance-cycle dans les séries de meurtres au Canada. Les séries à l'étude qui vont de 1961 à 1980 sont classées en deux grandes catégories, les suspects et les victimes. Seules les séries trimestrielles ont révélé une saisonnalité significative tout particulièrement au troisième trimestre. Nous avons également analysé la relation qui existe entre la tendance-cycle de la série de meurtres au Canada le taux de chômage et l'évolution démographique du groupe d'âge 15–44 ans.

1. INTRODUCTION

Case study No. 4 (Gentleman and Whitmore 1985), contains three independent studies of temporal patterns in twenty years of Canadian homicides. The three studies attempted to identify and estimate the effects of seasonality on series classified according to different attributes. Two of the three analyses, by McKie (1985) and by McLeod, MacNeill, and Bhattacharyya (1985), did not find significant seasonal variations for any of the monthly series according to the various tests available in Census Method II-X-11 variant and X-11-ARIMA, respectively. McLeod, MacNeill, and Bhattacharyya applied the same X-11-ARIMA tests to quarterly series and found seasonality in two out of the three series analyzed. These authors then tried another test to assess the presence of seasonality and obtained positive results for all of their monthly and quarterly series. Consequently, they estimated the seasonal effects using a regression-ARIMA method. The seasonal estimates, however, were not consistent with the fact that the effect of seasonality should cancel (or nearly cancel) annually. These authors obtained positive seasonality for each month, since their method did not constrain the coefficients to add to zero over a year period. Furthermore, some inconsistencies could be observed when going from monthly to quarterly data. For All Murders, the months of highest seasonal effect fell in the summer, but when transformed into quarterly data the seasonal peak fell in the fourth quarter. McLeod, MacNeill, and Bhattacharyya obtained similar inconsistencies when they applied the X-11-ARIMA method to the same data, but this program's tests indicated that the series should not be seasonally adjusted because no identifiable seasonality was present.

The third analysis, by Nakamura and Nakamura (1985), used a different approach. These authors fitted explanatory regression models to monthly data on homicides in 11 designated cities. They regressed the number of homicides against the days of the week, unemployment, and daily temperature variables, and found that homicides increased on Fridays but found no increase on Saturdays, in times of high unemployment, or in hot weather.

It has long been asserted by criminologists that there is a relationship between crime and the climatic seasons. But the presence of a seasonal effect has been hard to corroborate. Thus, Wolfgang (1975) cites several studies written prior to the fifties where seasonality was not found and others where some was found. However, we can attribute these frequently contradictory results from empirical studies to the rather noisy nature of homicide data and the fact that adequate seasonal adjustment methods were developed only after the sixties.

Having been involved for the last 15 years with theoretical and empirical problems related to seasonality, trend-cycle, and other time series components, we were prompted by the publication of the Canadian Homicides Case Study to take a new look at this old problem.

Our study concentrates mainly on the analysis of tree series, All Murders, All Victims, and All Suspects. These three series have been analyzed (1) before and after outlier removal, (2) for monthly, quarterly, and annual values (the last for long-term trend estimation), and (3) for several time spans. The period 1961–1980 and two subperiods (1961–1973 and 1974–1980) are used to estimate and analyze seasonal variations; the period 1961–1980 is used to estimate and analyze trend-cycle fluctuation, and 1960–1985 to estimate and analyze long-term trends.

Section 2 describes the selection of the series. Section 3 discusses the identification and estimation of seasonality. Section 4 analyzes the trend cycle and the long-term trend. Section 5 presents a regression model of the All Murders annual rates as a function of demographic and economic variables. Finally, Section 6 gives the conclusions of this study.

2. SELECTION OF THE SERIES

The data file for this study is fully described in Gentlemen and Whitmore (1985). It contains comprehensive records of all murders in Canada known to the police from 1961 through 1980 and all manslaughters and infanticides from 1974 to 1980. (Homicides are classified as murders, manslaughters, or infanticides.) The file includes the nature and circumstances of the homicide, the characteristics and relationships of the persons involved, and legal descriptions of the charges laid plus information about the subsequent court procedures. It is organized by incident. An incident is a single event in which a homicide is committed, regardless of the number of victims and known suspects. The file comprises 7784 homicide incidents, including data for 8625 victims and 7971 suspects.

In order to determine if there are temporal patterns in the Canadian murder time series, three monthly series were selected for analysis. The All Murders (AM) data refer to frequencies of all homicides—excluding manslaughters and infanticides, since they were not available for the entire period 1961 to 1980 (7364 murder cases out of the total number of 7784 homicide cases). The other two series are frequencies of All Victims (AV) and all Suspects (AS), from incidents which were classified as murders (8125 and 7551 persons respectively).

The analysis is performed at this aggregated level in order to obtain better seasonal and trend cycle estimates, as the time series are less contaminated with noise. An exploratory analysis has indeed confirmed that a finer disaggregation of the data, for example by different geographical locations, or means of offence, leads to less reliable or inconclusive results.

There are several factors relating to the nature and causes of murders [see, among others, Gould (1983) and Michael and Zumpe (1983)] that may affect the annual level of the series or have an effect on the intra-annual movement. However, they intermingle in such a way that the estimation of seasonal and trend cycle patterns can be inaccurate unless the noise in the series is significantly reduced. This can be achieved by removing outliers and/or by aggregating the data to higher levels, whether by frequency (from monthly to quarterly data) or by attributes (age, sex, others). Since outliers are valid observations, they are removed only when their presence distorts the identification and estimation of temporal patterns. Consequently, the All Victims (AV) monthly series has been modified by taking into account only the incidents with one victim, thus including 6879 persons. Similarly, outliers were removed from the All Suspects (AS) series, leaving the incidents with one suspect only (5474 persons). Finally, the All Murders series were modified by eliminating all cases which involved more than one victim or more than two suspects, leaving 6625 incidents.

The analysis has been made on the three original series, AM, AV, and AS, and on the corresponding modified series, denoted by AM1, AV1, and AS1. The latter three series are still distinct in their temporal patterns, especially during the earlier years, even though AM1 is a subset of AV1.

3. IS THERE A SEASONAL PATTERN IN CANADIAN MURDERS?

In the analysis of social and economic time series, it is traditional to decompose the observed series into four unobservable components, namely the trend, the cycle, the seasonal variations, and the irregular fluctuations. The seasonal variations represent the composite effect of climatic and institutional events which repeat more or less regularly each year. Seasonality, although unobservable, can be separated from the other forces that influence the movement of a socio-economic series by making assumptions about its nature. According to these assumptions, seasonal variations can be distinguished from trend by their oscillating character, from the cycle by being confined to an annual period, and from irregular fluctuations by their predictability.

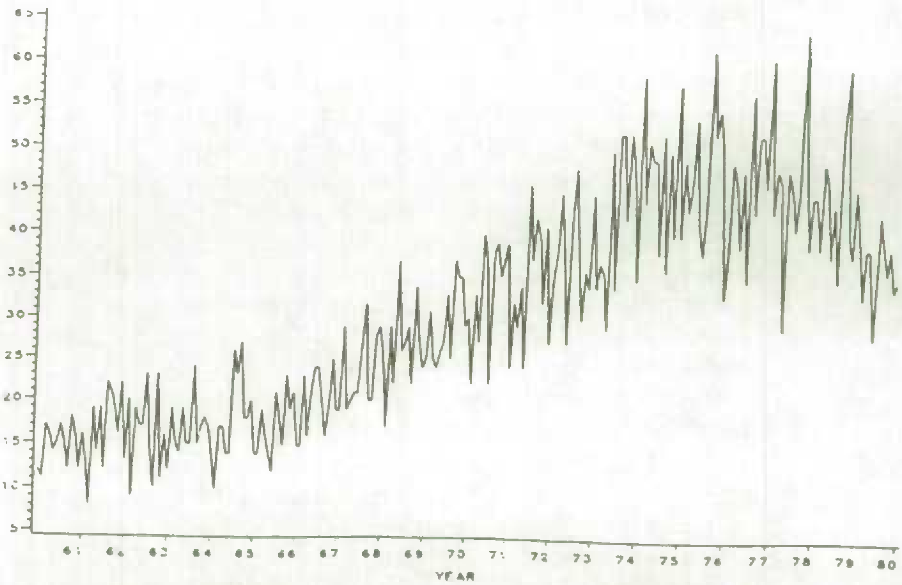


FIGURE 1: All murders (AM1) series, 1961 – 1980 (monthly; outliers removed).

There are numerous seasonal adjustment methods available today which estimate the seasonal component present in time series, among which the X-11 (Shiskin, Young, and Musgrave 1967) and X-11-ARIMA methods (Dagum 1980) are the most widely applied. The present study will make use of the X-11-ARIMA method for the detection and estimation of seasonality in murder data.

An obvious first step when analyzing any time series is to look at the graph of the data and see what patterns emerge. A visual inspection of the graphs of the six monthly series [a typical example of which, modified monthly, All Murders (AM1), is shown in Figure 1] does not give conclusive evidence of seasonality. It is difficult to tell if the intrayear fluctuations present in the series are strictly random or are dominated by a systematic annual pattern.

Since the presence of seasonality is not obvious from simply looking at the graphs, other tools are needed to determine if the series are affected by seasonal forces. The spectrum of the series can serve as such a diagnostic tool; it describes how the variation in a time series may be accounted for by cyclical components at different frequencies. Although the spectrum is strictly based on stationarity assumptions and most socioeconomic time series are not stationary, this problem can be solved in the case of actual data analysis with the concept of the pseudo-spectrum (Hatanaka and Suzuki 1967), which can be thought of as the average of a time-changing spectrum.

If a monthly time series is influenced by seasonal variations, the spectrum (or pseudospectrum) will exhibit relative peaks at seasonal frequencies, namely, $\frac{1}{12}$, $\frac{2}{12}$, $\frac{3}{12}$, $\frac{4}{12}$, $\frac{5}{12}$, and $\frac{6}{12}$ cycles per month. One-twelfth ($\frac{1}{12}$) is the fundamental seasonal frequency corresponding to a cycle which takes 12 months (a year) to complete, and the remaining five are its harmonics. If a series is dominated by a strong trend-cycle, it is often necessary to remove the trend first when searching for seasonal peaks; otherwise the high power at low trend-cyclical frequencies would make the seasonal peaks barely visible.

The spectrum of the modified monthly series All Murders (AM1) (not shown here for reasons of space) indicates that the corresponding seasonal frequencies are minimal compared to the high peaks occurring at frequencies associated with the irregular component. Thus the spectrum does not show evidence of a monthly seasonal pattern. The same conclusion can be drawn from applying a one-way analysis-of-variance test to the data after having removed the trend-cycle variations.

The first column in Table 1 gives the *F*-values obtained from the analysis-of-variance test for our six series.

Comparing the F-values in column 1 with standard F-table entries would give misleading results due to the autocorrelation of the error terms in the test. Empirical experience with thousands of series has shown (see Lothian and Morry 1978a) that the resulting F-values are highly inflated, and thus an F-value less than 5, 6, or 7 (depending on the degrees of freedom) would not be considered significant. Taking this into account, no monthly series has a significant F-statistic [two of the entries are even smaller than the 99th percentile of an F (11,239)]. These results are in accordance with the conclusions drawn from the spectrum of the series; i.e., there is no significant seasonality present in the monthly series. Furthermore, similar conclusions were obtained by McKie (1985) and McLeod, MacNeill, and Bhattacharyya (1985) for their monthly series of Canadian murders.

The second column in Table 1, under the heading "M-value", contains the results of another diagnostic test (Lothian and Morry 1978b) available in the X-11-ARIMA program. This measure gives an overall assessment of the seasonal adjustment quality (in the sense of its degree of accuracy) and is the weighted average of eleven other measures describing the relative size of seasonal versus irregular and trend-cycle versus irregular variations. The values of the *M*-statistic range from 0 to 3. Values between 0 and 1 indicate a reliable seasonally adjusted output; the closer to zero, the more reliable. Values between 1 and 1.5 indicate that the relative amount of irregular fluctuations is too high and consequently the seasonal adjustment quality is questionable. M-values greater than 1.5, such as the entries in column 2 of Table 1, are clearly an indication of unacceptable quality.

A further analysis was carried out using the monthly data; namely, the series were checked for the presence of a weekly pattern (sometimes referred to as testing for trading-day variations). In the series AM1, AV1, and AS1, Saturdays had high weights compared to other days in the week, but these weights were not significantly different from the average. Although high weights of weekend days agree with the

TABLE 1: Diagnostic test measures of six monthly and quarterly murder series for the period 1961–1980

	Monthly Series		Quarterly Series	
Series	F-Statistic	M-Value	F-Statistic	M-Value
AM	2.62	2.05	15.27*	1.21
AM1	2.81	2.03	24.03*	1.10
AV	1.67	2.11	10.04*	1.14
AV1	2.82	2.02	24.22*	1.08
AS	1.44	2.13	3.92	1.85
AS1	2.55	2.05	13.34*	1.54

*Significant F-value according to the X-11-ARIMA criteria.

belief that murders occur more frequently on the weekend than during the earlier part of the week, this type of analysis was not pursued, because of lack of confidence in the estimates of the irregular component obtained through the seasonal adjustment of the highly volatile monthly series.

Since the presence of a strong irregular component tends to obscure any possible seasonal pattern in the monthly series, a further possibility is to perform a temporal aggregation to produce quarterly totals of the same series. Forming quarterly series is equivalent to filtering out some of the irregular variations from the series, thus obtaining a smoother set of data. A glance at Figure 2, the spectrum of the differenced quarterly All Murders series, gives convincing evidence that forming quarterly totals is helpful in revealing a seasonal pattern. The very high peak at the quarterly fundamental seasonal frequency, 0.25 ($\frac{1}{4}$) cycle per quarter, is an indication of an annually repeating pattern in the quarterly series.

The analysis-of-variance test corroborates these results. Five out of the six series, as shown by the F-values in column 3 of Table I, have significant seasonality.

The second peak at frequency 0.39 cycles per quarter has no explicit meaning in terms of seasonality or trend-cycle and might be attributed to the data collection process, since we are dealing with administrative data.

From the F-values, it is also evident that seasonality is more prominent in the series AMI, AVI, and ASI, which have been smoothed by removing incidents with multiple victims or suspects. The M-statistics appearing in column 4 are also reduced substantially below the monthly equivalent values, although they still exceed 1.

These statistics indicate that a quarterly analysis of seasonality will be fruitful. In order to reveal the quarterly seasonal pattern, it is important to use the most informative procedure. At this state, it is helpful to return to the graphs of the quarterly unadjusted series (see Figure 3).

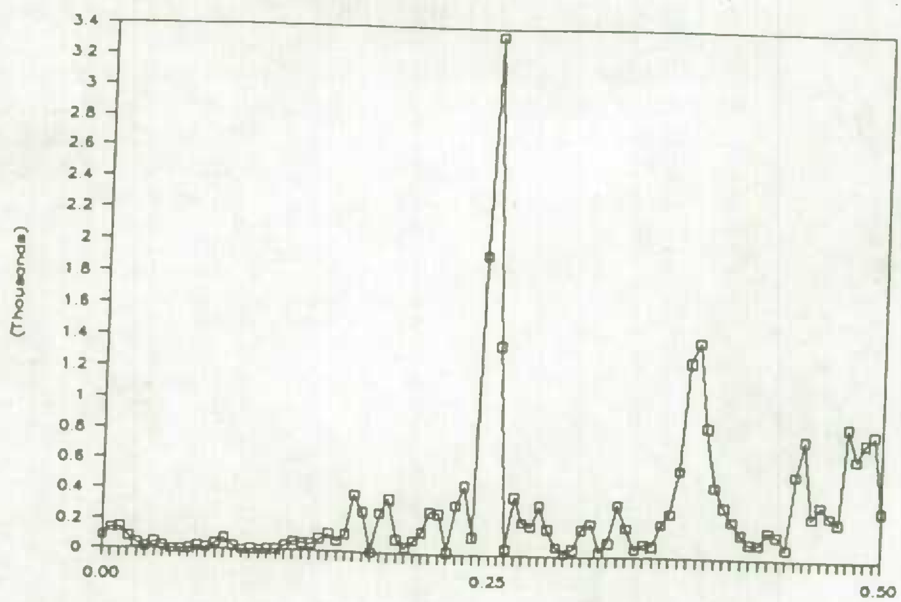


FIGURE 2: Power spectrum of the quarterly All Murders (AMI) series, 1961–1980.

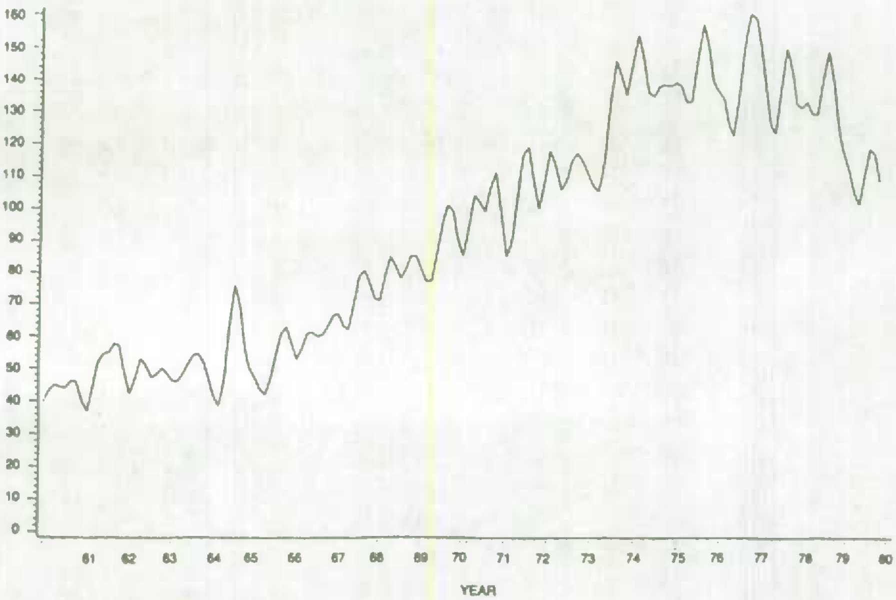


FIGURE 3: All Murders (AM1) series, 1961–1980 (quarterly; outliers removed).

As can be observed from the series AM1 in Figure 3, the appearance of the series changes considerably during the last third of the time span. There is a rise in the level, accompanied by much larger intrayear fluctuations around the trend than in previous years. The seasonal factors estimated during the exploratory seasonal adjustment showed a rapidly changing pattern in the early 1970s, suggesting the possibility of a break in the series around 1973–1974. On the basis of these findings, the series were split into two at the end of 1973 and were seasonally adjusted in two separate segments to obtain a more accurate estimate of the seasonal patterns corresponding to the two periods. Table 2 gives a quality assessment of the two sets of series by listing the F-statistics and M-values obtained by the X-11-ARIMA program.

It is apparent that the degree of accuracy of the last seven years of the seasonally adjusted data is much higher than that of the first thirteen (all the F-statistics are significant and all the M-values are less than 1). We wonder if this reflects a new

TABLE 2: Diagnostic tests measures of six quarterly murder series for the periods 1961–1973 and 1974–1980.

	1961–1973		1974–1980	
Series	F-Statistic	M-Value	F-Statistic	M-Value
AM	9.72[a]	1.46	26.33[a]	0.43[b]
AM1	11.60[a]	1.40	28.29[a]	0.60[b]
AV	6.73[a]	1.33	14.61[a]	0.62[b]
AV1	12.31[a]	1.33	25.44[a]	0.71[b]
AS	2.04	2.14	12.57[a]	0.73[b]
AS1	8.71[a]	1.78	21.02[a]	0.79[b]

[a]Significant F-value according to the X-11-ARIMA criteria.
[b]Significant *M*-value according to the X-11-ARIMA criteria.

pattern emerging in murders or is simply due to more accurate reporting practices on the part of the police coupled with improved data collection methods applied at Statistics Canada. Incidentally, the redesign in the new questionnaire form and in the format and content of the monthly publication also dates back to 1974. Thus it is possible that these new measures are responsible for the break in the series as well as for the improved quality of the recent data, but this cannot be substantiated. The fact remains that the seasonal adjustment of the second segment of the data provides us with reliable quarterly seasonal estimates, especially for the series AM1, AV1, and AS1.

What is then the seasonal pattern in murders? Figure 4 presents typical quarterly seasonal factors in three series (AM1, AV1, AS1) during the two time periods 1961 to 1973 and 1974 to 1980. It is evident that the systematic intrayear fluctuations changed substantially between the time periods. Whereas in the sixties and early seventies the seasonal low occurs in the first quarter, in the late seventies the second quarter shows the smallest number of murders in the course of a year. In the series AS1 the quarterly peak shifted from the fourth quarter in earlier years to the third quarter in later years to coincide with the peaks recorded by the other two series during the full timespan.

We cannot substantiate whether the *differences in seasonal pattern* between the early and more recent years are a result of recording practices or if they reflect a real change in criminal behavior regarding the annual pattern. It is also possible, as was mentioned previously, that the seasonal adjustment quality of the earlier years is not good enough to produce accurate seasonal factor estimates and this is why these estimates do not coincide with the more accurate seasonal factors of the last seven years.

In any event, from the point of view of policy making, it is more relevant to analyze the seasonal movements of recent years. The systematic quarter-to-quarter fluctuations between 1974 and 1980 are the same in all three series appearing in Figure 4 (and also in the three series AM, AV, AS not shown here). Slightly below average first-quarter figures drop to a trough in the second quarter registering around 8 to 9 per cent below the annual average. This is followed by an upsurge of criminal activity in the third quarter, with the number of incidents, victims, and suspects rising to a level of about 10 per cent above average. After this, the incidence of murders subsides and their number is just about average in the fourth quarter.

Whatever is the cause of the relatively high number of murders occurring in July, August, and September (irritability due to excessive heat, increased opportunities to "socialize" in the summer, etc.), it is evident that there is a consistent pattern which confirms the accepted notion that the rate of crimes committed against persons is highest in the summer. This information should be a consideration when planning manpower allocation, holiday scheduling, etc.

The seasonal patterns shown in Figure 4 represent the average of thirteen or seven years of data respectively. In order to find any possible trend in the seasonal behaviors, it is also important to examine the seasonal-factor estimates for each year in succession.

Figure 5 shows how the seasonal-factor estimates for the series AM1 moves through time. The break between the first thirteen and last seven years of data is quite evident even here. Our main concern, however, is the movement in fluctuation during the last seven years. There is an increase in the amplitude of seasonal swings around the annual average, indicating that seasonality plays a more important role

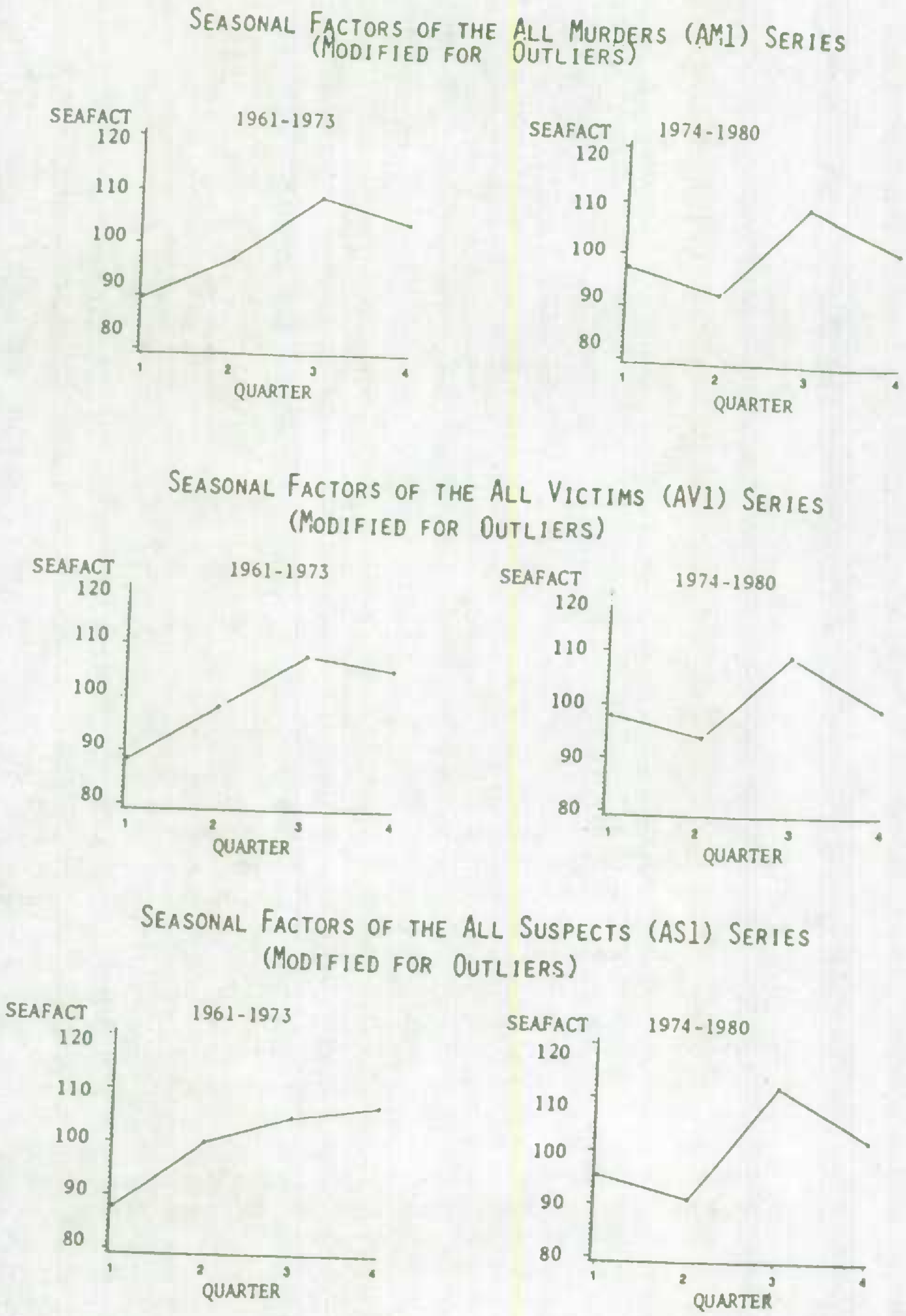


FIGURE 4: Average quarterly seasonal factors in murder series during the time spans 1961 to 1973 and 1974 to 1980 (outliers removed): (a) All Murders (AM1) series (b) All Victime (AV1) series; (c) All Suspects (AS1) series.

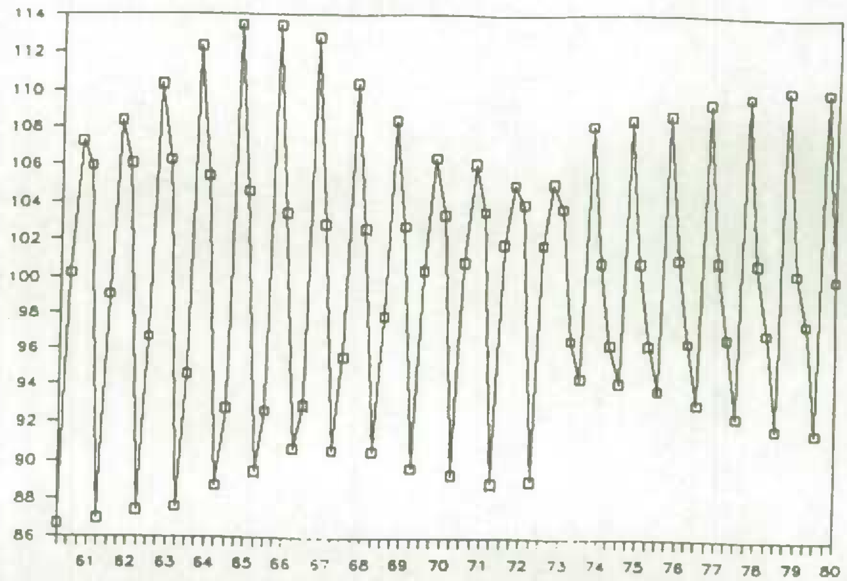


FIGURE 5: Quarterly seasonal factors for All Murders (AM1) series, 1961–1980.

now than in the early seventies. This is another factor which needs to be taken into account for effective crime prevention.

4. IS THERE A TREND PATTERN IN THE CANADIAN MURDERS?

To obtain trend-cycle estimates for the Canadian series, we seasonally adjusted the three quarterly series modified for outliers with the X-11-ARIMA program. This program applied a 7-term Henderson trend-cycle filter to the seasonally adjusted data. The frequency-response function of this filter does not modify the power of any frequencies associated with cycles longer than one and a half years and suppresses all shorter cyclical fluctuations (usually attributed to noise). Figure 6 shows the trend-cycle estimates of the modified All Murders (AM1) series for the period 1961–1980 obtained from the independently adjusted period 1961–1973 and 1974–1980.

It is apparent that the data are affected by cycles of short duration, as indicated by the frequent undulations in the graph. These quarterly trend-cycle estimates are useful for determining the direction of the *short-term* trend. They enable us to assess whether the series trend-cycle fluctuations are increasing or decreasing *within* the year or whether there is a cyclical turning point. Figure 6 shows that the trend and cyclical variations increased from 1961 till 1977 and then started to decrease. Similar patterns were observed for the other two series, AV1 and AS1 (not shown here).

In order to estimate the *long-term* trend in the Canadian murders, we used annual data which suppress most of the short cyclical variations and outliers if present. This long-term trend mainly reflects changes in the series which can be attributed to structural causes, whether economic, demographic, or institutional. Because the annual data, available for more recent years, are compatible with earlier data, the series were extended up to and including 1985. The last five years of data were obtained from Statistics Canada 1987. The enlarged series shows that the decrease in trend level that started in 1977 stopped at the end of 1980 and since then the trend has levelled off.

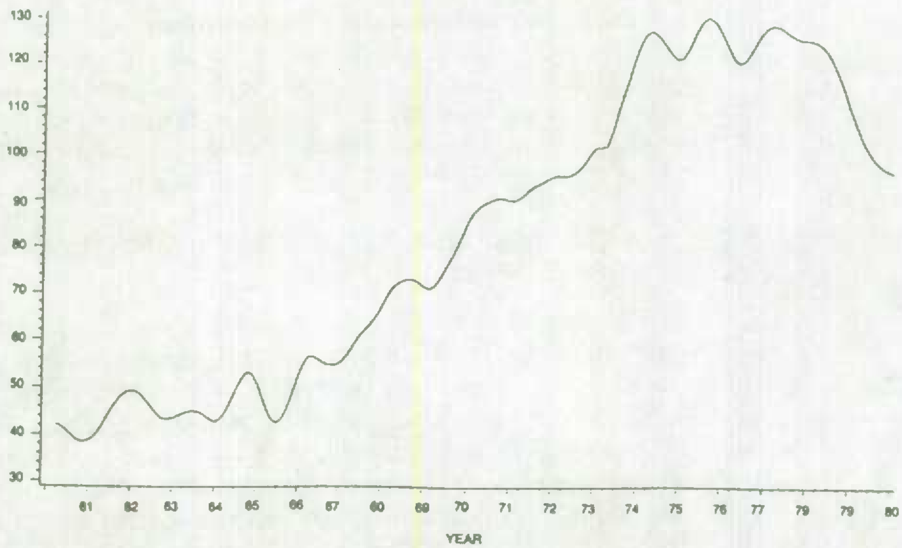
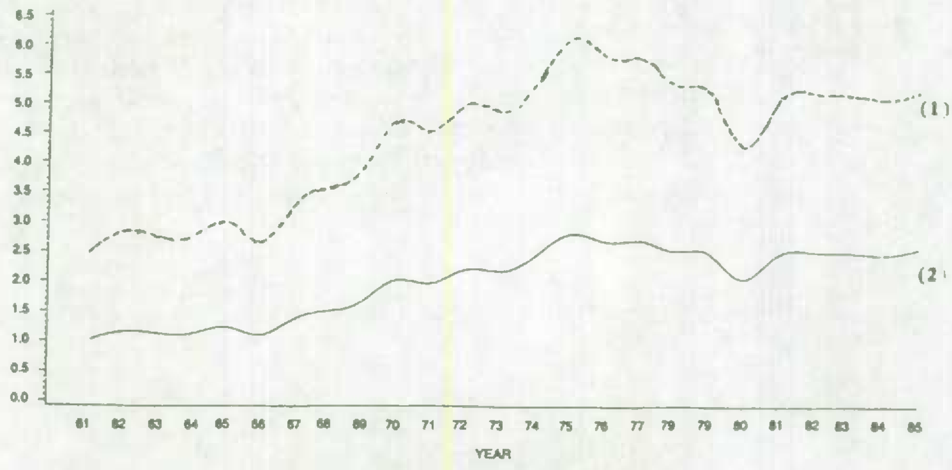


FIGURE 6: All Murders (AM1) quarterly trend cycle, 1961–1980 (outliers removed).

It is a common practice among criminologists to standardize the number of crimes by the size of the population. Therefore, we calculated the rate of murders per 100,000 inhabitants to see whether the pattern of the trend in real units would change when expressed as a rate. Figure 7 shows the annual trends of two murder rates—one as a function of the total population, and the other as a function of the high-risk age population (corresponding to the 15–44 age bracket). The trend patterns are similar except that the rate of change is smaller when the total population is used to obtain the murder rate.



1. HOMICIDES RATE STANDARDIZED WITH THE 15-44 POPULATION
2. HOMICIDES RATE STANDARDIZED WITH THE TOTAL POPULATION

FIGURE 7: All Murders rates, 1961–1985 (outliers removed), standardized with the 15–44 population (curve 1) and with the total population (curve 2).

The above results contradict the "constancy" of crime strongly urged by Quetelet (1842, p.6). The theory of constancy was also negated by Vold (1952). Vold showed that from 1933 to 1951 in the United States there was a gradual decrease in the rates of (1) murder and nonnegligent manslaughter, and (2) total homicides. Vold concluded that there was a general tendency toward a downward trend during the period analyzed except for 1945 and 1946, when an upturn was observed.

5. A REGRESSION MODEL OF CANADIAN TOTAL MURDER RATE FOR THE PERIOD 1966 TO 1985

The purpose of this section is to investigate some of the causes affecting the long-term trend. Several causes have been suggested in the literature. Quetelet (1842) indicated that some of the most important factors affecting crimes, whether against persons or properties, were age, sex, and sudden changes in economic conditions. Wolfgang (1975) and other authors have supported Quetelet's theory. From a statistical viewpoint, however, regression models built for the explanation of homicides or other crimes have not always been successful (see e.g. Wallis and Maliphant 1967, Tarling 1982, and Wilson and Herrnstein 1985). This may be attributed, among several other reasons, to the irregular character of the data and sometimes to the fact that researchers have tended to use highly disaggregated series for which very few observations were available.

The two main explanatory variables used in our regression models are (1) the rate of growth of the high-risk age population (one demographic variable) and (2) its corresponding unemployment rate (one economic variable). The high-risk age population is defined here as the 15–44 age group. Its definition is based on the frequency distribution of all Victims (AV) and All Suspects (AS) by age. The great majority of victims fall into the 15–44 age group. This age group was chosen to assess the impact of the demographic shift caused by the baby boom during the period 1966–1985.

The theories that relate unemployment to crime generally state that because unemployment implies financial hardship, the unemployed people would commit crime to alleviate it. Farrington et al. (1986) found that unemployment in young males (after leaving school) leads to higher rates of crime for material gains. These authors did not use a regression model, but based their study on individual records (longitudinal data), to which they fitted Poisson processes. Since it has been stated by other writers (e.g. Gillin 1946) that crimes may lead to murders, we test here whether

TABLE 3: Results from the regression model of annual murder rates as a function of the rate of change of the high-risk age (15–44) population (X_1) and its corresponding unemployment rate (X_2)

Independent variable	Coefficient	Std error	t-value	P-value
X_1	0.72	0.06	11.26	0.00
X_2	0.19	0.01	26.39	0.00

R-squared = 0.99
R-squared (adj. for d.f.) = 0.99
Durbin-Watson statistic = 1.73
Std. error of est. = 0.18
Mean absolute error = 0.15

TABLE 4: Analysis of variance for the full regression.

Source	Sum of Squares	DF	Mean square	F-Ratio	P-value
Model	100.39	2	50.19	1515.20	0.00
Error	0.56	17	0.03		
Total	100.95	19			

the unemployment rate is one of the explanatory variables of the long-term trend of Canadian murder rates.

The model was estimated using the standard assumptions of ordinary least squares (Ols). A constant term was originally included, but it was found statistically insignificant and thus eliminated. We also tried another model where all the variables were expressed as annual rates of change, but obtained a very low coefficient of determination. When only the exogeneous variables were expressed as annual rates of change, the unemployment rate was found statistically insignificant.

The model was fitted to annual data from 1966 till 1985 inclusive. The results obtained are given in Tables 3 and 4.

The results shown indicate that, of the two explanatory variables chosen, the demographic shift of the high-risk age population (X_1) affected the homicide rates more than the unemployment rate (X_2) during the period analyzed. Nevertheless, both independent variables are highly significant as shown by the t-values; the goodness of fit of the model is excellent, with an adjusted coefficient of determination of 0.99. The Durbin-Watson statistic indicates there is no autocorrelation of the residuals at a 5% level of significance. Figure 8 shows the plot of the residuals from the regression model.

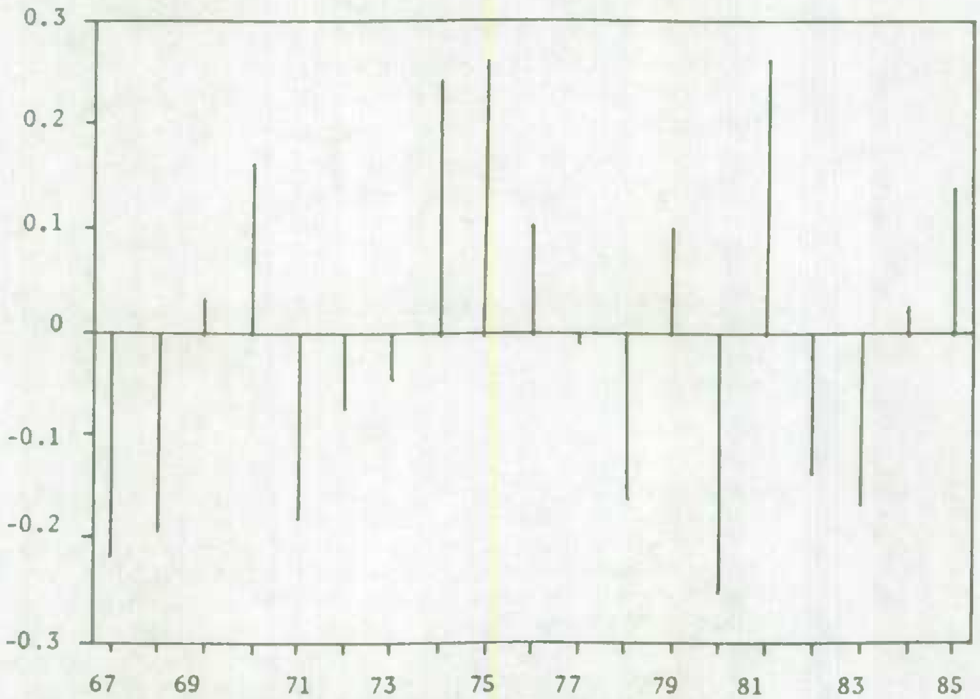


FIGURE 8: Plot of the residuals from the regression model.

6. CONCLUSIONS

This study was mainly concerned with the finding of temporal patterns in Canadian murders. Three main series, All Murders, All Victims, and All Suspects, were analyzed with and without removal of outliers and for monthly and quarterly data.

Concerning the identification and estimation of seasonal variations our main findings are:

(1) There is no identifiable seasonal movement in the monthly murder series. The quarterly series, with outliers excluded, on the other hand, display a well-defined seasonal pattern.

(2) There appears to be a structural break in the 1961–1980 quarterly series at the end of 1973. The quality of the more recent years' adjustment is superior to that of the first thirteen years.

(3) The quarterly seasonal patterns of homicide incidents, number of victims, and number of suspects coincide; namely, these numbers are slightly below average in the first quarter, drop to their lowest level in the second quarter, rise to a peak in the third quarter, and settle at an average level in the fourth quarter.

(4) In recent years we have observed an increasing seasonal amplitude in each series.

Concerning the identification and estimation of trend and cyclical variations, our main findings are:

(1) The three quarterly series modified for outliers, All Murders, All Victims, and All Suspects, have a well-defined trend-cycle.

(2) A regression model was fitted to the long-term trend of the total murder offences (victims) annual rate using two explanatory variables. The first explanatory variable was the rate of growth of the high-risk age (15–44) population, and the second was its corresponding unemployment rate. The model showed that both variables affected the murder rate positively, with the demographic shift of the high-risk age group having a larger impact than its unemployment rate. These results agree with theories supported by some criminologists (see e.g. Quetelet 1842, Wolfgang 1975, and Farrington *et al.* 1986).

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REFERENCES

Dagum, E.B. (1980). *The X-11-ARIMA Seasonal Adjustment Method*. Catalogue no. 12–564E. Statistics Canada, Ottawa.

Farrington, D.P.; Gallagher, B.; Morley, L.; St. Ledger, R.J., and West, D.J. (1986). Unemployment, school leaving, and crime. *British J. Criminol.*, 26 (4), 335–356.

Gentleman, J.F., and Whitmore, G.A. (1985). Temporal patterns in twenty years of Canadian homicides (Case Studies in Data Analysis, No. 4). *Canad. J. Statist.*, 13 (4), 261–291.

Gillin, J.L. (1946). *The Wisconsin Prisoner*. Univ. of Wisconsin Press, Madison.

Gould, S.J. (1983). Of crime, cause, and correlation. *Discover*, December, 34–43.

Hatanaka, M., and Suzuki, M. (1967). A theory of the pseudospectrum and its applications to non-stationary dynamic econometric models. *Essays in Mathematical Economics in Honor of Oskar Morgenstern* (Martin Shubik, *ed.*) Princeton Univ. Press.

Lothian, J., and Morry, M. (1978a). A test for the presence of identifiable seasonality when using the X-11 program. Research Paper, Seasonal Adjustment and Time Series Staff, Statistics Canada.

Lothian, J., and Morry, M. (1978b). A set of quality control statistics for the X-11-ARIMA seasonal adjustment method. Research Paper, Seasonal Adjustment and Time Series Staff, Statistics Canada.

McKie, G. (1985). Seasonality in Canadian homicides, 1961–1980. *Canad. J. Statist.*, 13 (4), 266–268.

McLeod, A.I.; MacNeill, I.B., and Bhattacharyya, J.D. (1985). Seasonal effects in Canadian murders. *Canad. J. Statist.*, 13 (4), 269–275.

Michael, R., and Zumpe, D. (1983). Sexual violence in the United States and the role of season. *Amer. J. Psychiatry*, 140, 883–886.

Nakamura, A., and Nakamura, M. (1985). A search for monthly fluctuation in Canadian homicides: 1965–1980. *Canad. J. Statist.*, 13 (4), 275–280.

Quetelet, M.A. (1842). *A Treatise on Man and the Development of his Faculties*. Republished by Burt Franklin, New York, 1968.

Shiskin, J., Young, A.H., and Musgrave, J.C. (1967). The X-11 variant of census method II seasonal adjustment. Technical Paper No. 15, Bureau of the Census, U.S. Department of Commerce.

Statistics Canada (1987), *Homicide in Canada (1986): A Statistical Perspective*. Catalogue 85-209. Canadian Centre for Justice Statistics.

Tarling, R. (1982). Unemployment and crime. *Home Office Res. Bull.*, 14, 28–33.

Vold, G. (1952). Extent and trend of capital crimes in the United States. *Ann. Amer. Acad. Polit. and Soc. Sci.*, (Murder and the Penalty of Death), 284, 1–7.

Wallis, C.P., and Maliphant, R. (1967). Delinquent areas in the County of London: Ecological factors. *British J. Criminol.*, 7, 250–284.

Wilson, J.Q., and Herrnstein, R.J. (1985). *Crime and Human Nature*. Simon and Schuster, New York.

Wolfgang, M.E. (1975). *Patterns in Criminal Homicide*. Patterson Smith, Montclair, N.J.

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Discussion

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The analysis of seasonality presented by Dagum, Huot, and Morry follows the traditional X-11-ARIMA approach. The major limitation of the X-11 approach and its variants is that the test for seasonality is based mainly on the empirical experience of X-11 practioners. Statements about significant seasonality and the measures of goodness of fit are based mainly on empiricism. Furthermore, no confidence intervals for the seasonal adjustment are available. As has been emphasized by Box (1981), theory and empiricism should interact in the development of good statistical models.

The Regression-ARIMA model suggested by McLeod, MacNeill, and Bhattacharyya (1985) is a step in the direction of a more theory-based seasonal-adjustment model. As pointed out by Dagum, Huot, and Morry, the method should be modified to constrain the sum of the seasonal effects to zero. In fact, such a modification is only necessary when there is a deterministic trend component present. The necessary modification is then simply to subtract the mean from the differenced or seasonally differenced series. Further work on the Regression-ARIMA seasonal adjustment approach will be reported in a future article.

The X-11-ARIMA procedures test for seasonality and for moving seasonality using standard F-tests. However, recent studies of time-series-valued experimental design show that autocorrelation in the series used to define the numerator and denominator of the F-ratios invalidate the standard distribution theory. There are two reasons for this: first, the numerator and denominator are correlated; and second and more importantly, the autocorrelation in the series can cause the mean sums of squares to be badly biased as estimators of the residual variance. The effects of these biases are discussed by Sutradhar, MacNeill, and Sahrmann (1987), particularly in the case of time-series-valued experimental design with AR(P) errors. For the one-way classification with AR(1) errors, appropriate modifications are suggested for the degrees of freedom to account for the reduction in information conveyed by the autocorrelated errors. The overall effect on the F-ratio depends upon sample size, but for a wide range of sample size, this effect can be approximately compensated for by multiplying the F-ratio by $(1-\phi)/(1+\phi)$, $|\phi| < 0.9$, where ϕ is the AR(1) parameter. Hence, for large values of ϕ, the effect of autocorrelation is substantial enough to make the standard F-tables of little practical use for hypothesis testing. The theory of time-series-valued experimental designs is being extended to seasonal models.

REFERENCES IN COMMENTS

Box, G.E.P. (1981). An apology for ecumenism in statistics. *Scientific Inference, Data Analysis and Robustness* (G.E.P. Box, T. Leonard and C. Wu, *eds.*). Academic Press, New York, 51–84.

McLeod, A.I.; I.B. MacNeill, and J.D. Bhattacharyya (1985). Seasonal effects in Canadian murders. *Canad. J. Statist.*, 13, 269–275.

Sutradhar, B.C.; I.B. MacNeill, and H.F. Sahrmann (1987). Time series valued experimental designs: One-way analysis of variance with autocorrelated errors. *Time Series and Econometric Modelling* (I.B. MacNeill and G.J. Umphrey, *eds.*). D. Reidel, Dordrecht, 113–129.

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Granger (1984, p.335) states:

> The most obvious approach to modelling this [seasonal] component [of the monthly demand for electricity] is to consider why the seasonal component exists and why it has its particular shape and thus consider the explanatory variables, which themselves will be seasonal, such as temperature, humidity, and the timing of public and school vacations. A regression procedure will then model the seasonal component, and adjustment or removal of this component is straight forward.

Nakamura and Nakamura (1985) applied such a regression procedure in an effort to relate monthly fluctuations in Canadian homicide activity to monthly variations in the numbers of Fridays and Saturdays, the unemployment rate, and the average temperature. Regression equations were estimated for eleven cities as well as for the whole of Canada. Nakamura and Nakamura found monthly fluctuations in homicide activities to be associated with the number of Fridays in the month and with variations in below-zero average temperatures. They conclude their analysis by suggesting that better empirical results could be obtained if information on the day of occurrence of each homicide, as well as the outside temperature at the time of occurrence, were added to the information Statistics Canada currently compiles on homicides. U.S. evidence suggests a sharp rise in homicide activity on Fridays and Saturdays, and there has been persistent interest in possible associations between homicide activity and climatic factors such as the temperature. Addition of the suggested variables would permit more rigorous testing of hypotheses concerning these factors. If it were possible to control more adequately for day of the week and temperature-related patterns, it might also be easier to identify fluctuations associated with other variables such as the unemployment rate. Adding information about the day (and even the time) of occurrence would entail very little extra expense, since this information is available in the original crime reports which are the primary data source.

While promoting causally based regression adjustments for seasonality of the sort used by Nakamura and Nakamura, Granger (1984, p.335) acknowledges that these methods are rarely used, probably because of the expense, and that the methods used are almost exclusively autoadjustments. The latter have been traditionally used in economic statistics as well (see for example, Bell and Hillmer 1984). In particular, the U.S. Bureau of Census Method II X-11 and its Statistics Canada modification X-11-ARIMA, although developed to analyze seasonality in economic time series, can also be applied to noneconomic series. For example, Sakamoto-Momiyama (1977, Chapter 6) has applied the Census X-11 method to analyze seasonal patterns in mortality in Tokyo, London, and New York, and attributes the smaller seasonal variations in New York to the effects of central heating in that city.

Dagum, Huot, and Morry use the X-11-ARIMA method in their analysis of seasonality in Canadian homicide activity. They find that the quarterly time series for All Murders, All Victims, and All Suspects for the period of 1974 through 1980 display a well-defined, common seasonal pattern. In particular they are able to accept the hypothesis that the murder rate is highest in summer (July, August, and September). This clear-cut result is in contrast to earlier findings (McKie 1985; and McLeod, MacNeill, and Bhattacharyya 1985). Dagum, Huot, and Morry suggest that their finding that the murder rate is highest in summer "should be a consideration when planning manpower allocation, holiday scheduling, etc."

Dagum, Huot, and Morry's analysis is carefully executed and thought-provoking. Nevertheless it seems premature to recommend using their findings (or any other Canadian findings, including our own) as a basis for allocation of law-enforcement personnel, holiday planning, and so forth. Planning of this sort would only be affected in a substantial way by pronounced and regular seasonal variations, yet Dagum, Huot, and Morry note the lack of conclusive evidence of seasonality. This is a compelling reason, as they suggest, for using "other tools. . .to determine if the series are affected by seasonal forces." It also suggests, however, that the seasonal fluctuations may not be pronounced and regular enough to have important planning implications of the sort suggested above.

Nevertheless the seasonal pattern that Dagum, Huot, and Morry identify could provide important clues concerning causal factors affecting homicide activity. This is the direction in which we believe research attention should be focussed, in the hopes that an improved understanding of various sorts of homicidal behavior will point the way towards effective means of curbing this behavior. The finding that the murder rate rises in the summer raises a series of questions. Are Canadian summers really hot enough, for instance, for this pattern to be attributable to "irritability due to excessive heat" as Dagum, Huot, and Morry suggest? Could it be caused in part by work-related factors such as the seasonal migration patterns of itinerant labourers? Could seasonal changes in social behavior be part of the explanation, as Dagum, Huot, and Morry also suggest?

Dagum, Huot, and Morry (p.5) contend that "a finer disaggregation of the data. . .leads to less reliable or inconclusive results." This finding is probably an inherent limitation of their methodology in dealing with a fairly rare event like murder. Yet it is precisely such a disaggregation by city and type of homicide which might permit Dagum, Huot, and Morry to build on their present results by relating city-specific seasonal patterns for particular types of homicides to city-specific climatic, economic, social, and demographic patterns, following the example set by Sakamoto-Momiyama in her mortality study. Such an extension, if feasible, would complement the behaviorally oriented regression approach adopted by Nakamura and Nakamura. Moreover, the addition of information about the day of the week as well as the month of occurrence to the homicide information compiled by Statistics Canada would probably enhance the potential effectiveness of both approaches.

REFERENCES IN DISCUSSION

Bell, W.R., and Hillmer, S.C. (1984). Issues with the seasonal adjustment of economic time series. *J. Business & Econom. Statist.*, 2, 291–320.

Granger, C.W.J. (1984). Comment. *J. Business & Econom. Statist.*, 2, 335–336.

McKie, C. (1985), Seasonality in Canadian homicides, 1961–1980. *Canad. J. Statist.*, 13, 266–268.

McLeod, A.I.; MacNeill, I.B., and Bhattacharyya, J.D. (1985). Seasonal effects in Canadian murders. *Canad. J. Statist.*, 13, 269–275.

Nakamura, A., and Nakamura, M. (1985). A search for monthly fluctuation in Canadian homicides: 1965–1980. *Canad. J. Statist.*, 13, 275–280.

Sakamoto-Momiyama, M. (1977). *Seasonality in Human Mortality*. University of Tokyo Press, Tokyo.