

THE USE OF PROC ARIMA TO PERFORM TIME-SERIES INTERVENTION ANALYSIS  
OF THE IMPACT OF THE TEXAS 1989 MOTORCYCLE HELMET LAW ON  
TOTAL AND HEAD-RELATED FATALITIES

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INTRODUCTION. The State of Texas implemented a mandatory total motorcycle helmet law for all operators and passengers, effective September 1, 1989. This paper discusses the use of PROC ARIMA to quantify the impact of this intervention on frequency of both total and head-related fatalities. PROC ARIMA is used to implement the Box-Tiao time-series intervention methodology/transfer function analysis for estimating secular trends before and changes after the implementation of the law, analyzing Department of Public Safety monthly injury accident data over a six year period. This information was collected from traffic accident reports filed for each motorcycle injury accident.

Model specification (including data preparation and programming code in SAS), parameter estimation, and interpretation of SAS output for both total and head-related fatalities are presented. The resulting estimated trends in total fatalities prior to the law approximated the 9.4% average annual decline in motorcycle registrations. Additional declines of 12.6% and 57.0%

were estimated for total and head-related fatalities during the year after the law.

Table 1 shows the data summarized on an annualized basis since 1985, from the published article by Fleming and Becker (1992). These are the number of motorcycle operators killed in total and from head-related accidents from September 1984 through August, 1990 -- a year after the implementation of the law. The decline in monthly registrations necessitates the use of the Box-Tiao methodology. This is because failure to consider trends prior to the law's implementation would bias estimation of the true impact. The monthly fatality data can also be seen in Figure 1 from the published article by Fleming and Becker (1992).

STATISTICAL THEORY. The time-series model uses monthly information to determine a "before" baseline level and "after" effect, as a "quasi-experimental" design described by Campbell and Stanley (1966). The model assumes that data collected at equal intervals are autocorrelated, i.e., correlated with previous data points.

Errors (residuals) resulting from the often used ordinary least squares (OLS) regression are often autocorrelated, a violation of the OLS assumption. OLS estimation of parameters becomes inefficient, providing estimators that do not possess minimum error. Alternatively, the Box-Tiao (1981) intervention analysis is based on the Box-Jenkins autoregressive, integrated, moving average (ARIMA) model that considers the time-dependent nature of the data to produce efficient estimation. In addition to Box and Tiao (1981), McDowall et al. (1980), Vandaele (1983), and

Table 1. Number of Motorcycle Operators Killed in Total and from Head-Related Injury Accidents, from September, 1984 through August, 1990 annually in Texas; and number of motorcycle registrations by calendar year.

| Year    | Registrations* |          | Total**<br>Fatalities |          | Head-Related**<br>Fatalities |          |
|---------|----------------|----------|-----------------------|----------|------------------------------|----------|
|         | Number         | % Change | Number                | % Change | Number                       | % Change |
| 1984    | 309,015        |          |                       |          |                              |          |
| 1985    | 277,551        | -10.2%   | 310                   |          | 140                          |          |
| 1986    | 248,715        | -10.4%   | 358                   | 15.5%    | 168                          | 20.0%    |
| 1987    | 226,038        | -9.1%    | 253                   | -29.3%   | 111                          | -33.9%   |
| 1988    | 207,976        | -8.0%    | 252                   | -0.4%    | 141                          | 27.0%    |
| 1989    | 187,687        | -9.8%    | 226                   | -10.3%   | 127                          | -9.9%    |
| 1990    | 170,642        | -9.1%    | 168                   | -25.7%   | 53                           | -58.3%   |
| Average |                | -9.4%    |                       | -10.0%   |                              | -11.0%   |

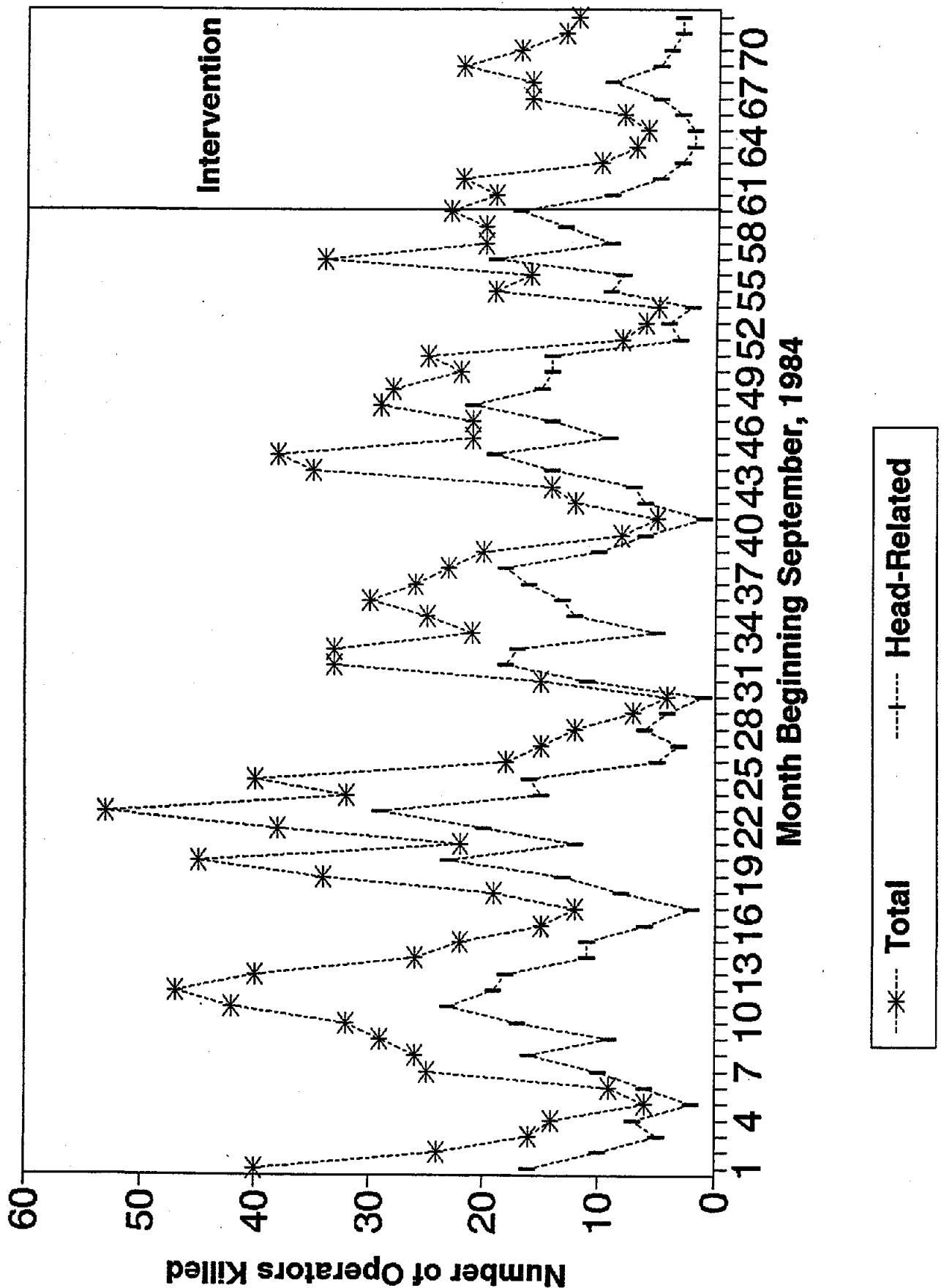
\*Based on Calendar Year.

\*\*Based on Year Beginning September 1, of previous year.

Source: N.S. Fleming, E.R. Becker, "The Impact of the Texas 1989 Motorcycle Helmet Law on Total and Head-Related Fatalities, Severe Injuries, and Overall Injuries," Medical Care, September, 1992.

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**Fig 1. Number of Motorcycle Operators Killed: Sep, 1984-Aug, 1990 in Texas**



Wei (1990) have all demonstrated examples of this form of time-series intervention analysis.

ARIMA specifically models a dependent variable as a function of itself lagged from previous period(s) -- autocorrelation; and random errors lagged from previous period(s) -- moving average. Since an assumption is that the time-series is stationary, i.e., has an equal mean and variance, 12<sup>th</sup> order differencing (integration) of monthly observations  $Y_t$  and  $Y_{t-12}$  was needed to eliminate the annual trend with these data.

To quantify both annual trend and the intervention in terms of percentage, the twelfth order difference between the natural logarithms of the monthly observations was computed to create the variable  $Z_t$ :

$$Z_t = \log Y_t - \log Y_{t-12}$$

The following ARIMA equation includes the abrupt effect of the helmet law on the dependent variable after August 31, 1989:

$$Z_t = \mu + \omega_0 I_t + \frac{\theta_q(B)}{\phi_p(B)} a_t$$

$Z_t$  is the dependent variable representing motorcycle fatalities (including head-related) and  $\mu$  is the annual trend, i.e., the mean of the twelfth order difference between the natural logarithms of monthly figures prior to (adjusting for) the law's impact.  $\omega_0$  is the abrupt effect of the motorcycle helmet law on the dependent variable during the following twelve months, i.e., the percentage change after the law's implementation.  $B$  is the

backshift operator, and  $I_t$  is a dummy vector with a value of 0 prior to September 1, 1989 and 1 thereafter for the twelve months through August 31, 1990.

The right-hand side of the right-hand part of the equation represents the ARIMA noise process. The  $a_t$  represents a stationary (with 0 mean and constant variance), white noise (0 covariance between error lags) process. The  $\theta_q$  and  $\phi_p$  are the coefficients of the noise model moving average and autoregressive factors (see Vandaele (1983) and Wei (1990)).

The  $a_t$  represent population residuals, i.e., the difference of  $Z_t$  and  $Z_{t-12}$  computed from population parameters, and are assumed normally distributed for purposes of significance testing.

DATA. Motorcycle accident injury information on operators was collected from motor vehicle traffic accident reports filed with the State of Texas DPS. The aggregated fatality information from these reports is submitted annually to the National Highway Traffic Safety Administration in the Fatal Accident Reporting System.

The DPS accident reports also contain information separately for vehicle operators and passengers. Since the change in helmet wearing requirements occurred for individuals eighteen years of age and older, information was examined for those individuals only. Information was only examined in this study for operators rather than including passengers.

Since information is also recorded on the body site of primary injury, head-related occurrences were computed as the sum of

injuries at the head, head and chest, head and neck, and head and arms/legs.

METHODS. The dependent variable  $Z_t$  was computed as the twelfth order difference between the natural logarithms of the monthly observations,  $Y_t$  and  $Y_{t-12}$ . Trend effects were modelled as the constant in the equation, with all observations having a value of 1. Intervention effects were modelled using a dummy vector where:

$$I_t = \begin{cases} 0, & t \leq 60 \text{ (September, 1984 - August, 1989)} \\ 1, & t \geq 61 \text{ (September, 1989 - August, 1990)} \end{cases}$$

Computations were performed using the SAS/ETS statistical computer software package on the PC. PROC ARIMA has the option to use a method based on maximum likelihood to estimate parameters after obtaining initial values from conditional least squares (SAS Institute, 1989).

#### TOTAL FATALITIES

SAS CODE. The following SAS code was used to perform the time-series intervention analysis, computation of R square, and analysis of normality of the residuals for the total operator fatality data:

```
/*ARIMA MODELLING OF TEXAS MOTORCYCLE DEATHS*/;
OPTIONS PAGENO=1;
DATA RESID.MOTOR;
INPUT TDEATHS TINJURED;
LTDEATHS=LOG(TDEATHS);
LTINJURE=LOG(TINJURED);
IF _N_ GT 60 THEN INTER=1;
ELSE INTER=0;
```

CARDS;

(Data observations are inserted here)

RUN;

%LET DEPVAR=LTDEATHS;

PROC ARIMA DATA=RESID.MOTOR;

FORECAST LEAD=12;

IDENTIFY VAR=&DEPVAR(12) CROSSCOR=(INTER(12)) NLAG=12 NOPRINT;

ESTIMATE Q=(12) INPUT=(INTER) ML;

FORECAST LEAD=12 OUT=AUTO;

RUN;

PROC CORR DATA=AUTO;

VAR FORECAST;

WITH &DEPVAR;

RUN;

PROC UNIVARIATE DATA=AUTO PLOT NORMAL;

VAR RESIDUAL;

RUN;

RESULTS. The code produced the following results:

\*\*\* TEXAS MOTORCYCLE ANALYSIS \*\*\*  
Based on actual data from OCT 1984 through SEP 1990

8:11 Friday, September 18, 1992 1

ARIMA Procedure

Name of variable = LTDEATHS.

Period(s) of Differencing = 12.

Mean of working series = -0.10818

Standard deviation = 0.440503

Number of observations = 50

NOTE: The first 12 observations were eliminated by differencing.

Autocorrelations

| Lag | Covariance | Correlation | -1 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0     | 1     | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 1 | Std      |
|-----|------------|-------------|----|---|---|---|---|---|---|---|---|---|-------|-------|---|---|---|---|---|---|---|---|---|----------|
| 0   | 0.194043   | 1.00000     |    |   |   |   |   |   |   |   |   |   |       | ***** |   |   |   |   |   |   |   |   |   | 0        |
| 1   | 0.041949   | 0.21619     |    |   |   |   |   |   |   |   |   | . |       | ****. |   |   |   |   |   |   |   |   |   | 0.129099 |
| 2   | 0.042221   | 0.21759     |    |   |   |   |   |   |   |   |   | . |       | ****. |   |   |   |   |   |   |   |   |   | 0.134998 |
| 3   | 0.029793   | 0.15354     |    |   |   |   |   |   |   |   |   | . |       | ***.  |   |   |   |   |   |   |   |   |   | 0.140722 |
| 4   | 0.033047   | 0.17031     |    |   |   |   |   |   |   |   |   | . |       | ***.  |   |   |   |   |   |   |   |   |   | 0.143487 |
| 5   | 0.020414   | 0.10520     |    |   |   |   |   |   |   |   |   | . |       | **.   |   |   |   |   |   |   |   |   |   | 0.146817 |
| 6   | 0.020528   | 0.10579     |    |   |   |   |   |   |   |   |   | . |       | **.   |   |   |   |   |   |   |   |   |   | 0.148058 |
| 7   | -0.0016381 | -0.00844    |    |   |   |   |   |   |   |   |   | . |       | .     |   |   |   |   |   |   |   |   |   | 0.149323 |
| 8   | -0.031376  | -0.16170    |    |   |   |   |   |   |   |   |   | . | ***   | .     |   |   |   |   |   |   |   |   |   | 0.149331 |
| 9   | 0.0075878  | 0.03910     |    |   |   |   |   |   |   |   |   | . | *     | .     |   |   |   |   |   |   |   |   |   | 0.152221 |
| 10  | -0.028383  | -0.14627    |    |   |   |   |   |   |   |   |   | . | ***   | .     |   |   |   |   |   |   |   |   |   | 0.152388 |
| 11  | -0.027393  | -0.14117    |    |   |   |   |   |   |   |   |   | . | ***   | .     |   |   |   |   |   |   |   |   |   | 0.154711 |
| 12  | -0.104137  | -0.53667    |    |   |   |   |   |   |   |   |   | . | ***** | .     |   |   |   |   |   |   |   |   |   | 0.156843 |

"," marks two standard errors

Inverse Autocorrelations

| Lag | Correlation | -1 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1   | 0     | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 1 |
|-----|-------------|----|---|---|---|---|---|---|---|---|-----|-------|---|---|---|---|---|---|---|---|---|---|
| 1   | -0.07920    |    |   |   |   |   |   |   |   | . | **  |       | . |   |   |   |   |   |   |   |   |   |
| 2   | -0.04154    |    |   |   |   |   |   |   |   | . | *   |       | . |   |   |   |   |   |   |   |   |   |
| 3   | -0.10563    |    |   |   |   |   |   |   |   | . | **  |       | . |   |   |   |   |   |   |   |   |   |
| 4   | 0.04787     |    |   |   |   |   |   |   |   | . |     | *     | . |   |   |   |   |   |   |   |   |   |
| 5   | -0.01206    |    |   |   |   |   |   |   |   | . |     | .     | . |   |   |   |   |   |   |   |   |   |
| 6   | -0.14780    |    |   |   |   |   |   |   |   | . | *** | .     | . |   |   |   |   |   |   |   |   |   |
| 7   | -0.00082    |    |   |   |   |   |   |   |   | . |     | .     | . |   |   |   |   |   |   |   |   |   |
| 8   | 0.10882     |    |   |   |   |   |   |   |   | . |     | **    | . |   |   |   |   |   |   |   |   |   |
| 9   | -0.15279    |    |   |   |   |   |   |   |   | . | *** | .     | . |   |   |   |   |   |   |   |   |   |
| 10  | 0.00411     |    |   |   |   |   |   |   |   | . |     | .     | . |   |   |   |   |   |   |   |   |   |
| 11  | -0.03031    |    |   |   |   |   |   |   |   | . | *   | .     | . |   |   |   |   |   |   |   |   |   |
| 12  | 0.37608     |    |   |   |   |   |   |   |   | . |     | ***** |   |   |   |   |   |   |   |   |   |   |

ARIMA Procedure

Partial Autocorrelations

| Lag | Correlation | -1 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0     | 1     | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 1 |
|-----|-------------|----|---|---|---|---|---|---|---|---|---|-------|-------|---|---|---|---|---|---|---|---|---|
| 1   | 0.21619     |    |   |   |   |   |   |   |   |   | . |       | ****. |   |   |   |   |   |   |   |   |   |
| 2   | 0.17923     |    |   |   |   |   |   |   |   |   | . |       | ****. |   |   |   |   |   |   |   |   |   |
| 3   | 0.08257     |    |   |   |   |   |   |   |   |   | . |       | **    | . |   |   |   |   |   |   |   |   |
| 4   | 0.10004     |    |   |   |   |   |   |   |   |   | . |       | **    | . |   |   |   |   |   |   |   |   |
| 5   | 0.02217     |    |   |   |   |   |   |   |   |   | . |       | .     |   |   |   |   |   |   |   |   |   |
| 6   | 0.03233     |    |   |   |   |   |   |   |   |   | . |       | *     | . |   |   |   |   |   |   |   |   |
| 7   | -0.08258    |    |   |   |   |   |   |   |   |   | . | ***   | .     |   |   |   |   |   |   |   |   |   |
| 8   | -0.21767    |    |   |   |   |   |   |   |   |   | . | ****  | .     |   |   |   |   |   |   |   |   |   |
| 9   | 0.09403     |    |   |   |   |   |   |   |   |   | . |       | **    | . |   |   |   |   |   |   |   |   |
| 10  | -0.13398    |    |   |   |   |   |   |   |   |   | . | ***   | .     |   |   |   |   |   |   |   |   |   |
| 11  | -0.09393    |    |   |   |   |   |   |   |   |   | . | **    | .     |   |   |   |   |   |   |   |   |   |
| 12  | -0.50788    |    |   |   |   |   |   |   |   |   | . | ***** | .     |   |   |   |   |   |   |   |   |   |

Autocorrelation Check for White Noise

| To  | Chi    | Autocorrelations |       |        |        |       |        |        |        |  |  |
|-----|--------|------------------|-------|--------|--------|-------|--------|--------|--------|--|--|
| Lag | Square | DF               | Prob  |        |        |       |        |        |        |  |  |
| 6   | 10.97  | 6                | 0.089 | 0.216  | 0.218  | 0.154 | 0.170  | 0.105  | 0.106  |  |  |
| 12  | 38.38  | 12               | 0.000 | -0.008 | -0.162 | 0.039 | -0.146 | -0.141 | -0.537 |  |  |

ARIMA Procedure

Maximum Likelihood Estimation

|           |          | Approx.   |         |     |          |       |
|-----------|----------|-----------|---------|-----|----------|-------|
| Parameter | Estimate | Std Error | T Ratio | Lag | Variable | Shift |
| MU        | -0.10114 | 0.02499   | -4.05   | 0   | LTDEATHS | 0     |
| MA1,1     | 0.85365  | 0.38057   | 2.24    | 12  | LTDEATHS | 0     |
| NUM1      | -0.13416 | 0.11190   | -1.20   | 0   | INTER    | 0     |

Constant Estimate = -0.101137

Variance Estimate = 0.10345156

Std Error Estimate = 0.32163887

AIC = 50.7843358

SBC = 57.0673695

Number of Residuals= 60

Correlations of the Estimates

| Variable | Parameter | LTDEATHS | LTDEATHS | INTER  |
|----------|-----------|----------|----------|--------|
|          |           | MU       | MA1,1    | NUM1   |
| LTDEATHS | MU        | 1.000    | -0.031   | -0.643 |
| LTDEATHS | MA1,1     | -0.031   | 1.000    | -0.001 |
| INTER    | NUM1      | -0.643   | -0.001   | 1.000  |

Autocorrelation Check of Residuals

|     |        | Chi |       | Autocorrelations |        |        |        |        |        |  |
|-----|--------|-----|-------|------------------|--------|--------|--------|--------|--------|--|
| Lag | Square | DF  | Prob  |                  |        |        |        |        |        |  |
| 6   | 4.12   | 5   | 0.532 | 0.164            | 0.042  | 0.083  | 0.098  | 0.085  | 0.104  |  |
| 12  | 10.18  | 11  | 0.514 | 0.015            | -0.191 | -0.003 | -0.156 | -0.092 | -0.112 |  |
| 18  | 16.12  | 17  | 0.516 | -0.007           | -0.218 | -0.143 | 0.011  | -0.048 | -0.046 |  |
| 24  | 20.40  | 23  | 0.617 | -0.001           | -0.059 | -0.155 | 0.038  | -0.024 | 0.119  |  |

Model for variable LTDEATHS

Estimated Intercept = -0.101137

Period(s) of Differencing = 12.

Moving Average Factors

Factor 1: 1 - 0.85365 B\*\*(12)

Input Number 1 is INTER.

Period(s) of Differencing = 12.

Overall Regression Factor = -0.13416

ARIMA Procedure

Forecasts for variable LTDEATHS

| Obs | Forecast | Std Error | Lower 95% | Upper 95% |
|-----|----------|-----------|-----------|-----------|
| 73  | 2.9607   | 0.3216    | 2.3303    | 3.5911    |
| 74  | 2.6639   | 0.3216    | 2.0335    | 3.2943    |
| 75  | 2.3926   | 0.3216    | 1.7622    | 3.0230    |
| 76  | 1.8490   | 0.3216    | 1.2186    | 2.4794    |
| 77  | 1.4474   | 0.3216    | 0.8170    | 2.0778    |
| 78  | 1.6582   | 0.3216    | 1.0278    | 2.2886    |
| 79  | 2.5072   | 0.3216    | 1.8768    | 3.1376    |
| 80  | 2.7987   | 0.3216    | 2.1683    | 3.4291    |
| 81  | 2.9240   | 0.3216    | 2.2936    | 3.5544    |
| 82  | 2.7011   | 0.3216    | 2.0707    | 3.3315    |
| 83  | 2.7626   | 0.3216    | 2.1322    | 3.3930    |
| 84  | 2.7955   | 0.3216    | 2.1651    | 3.4259    |

\*\*\* TEXAS MOTORCYCLE ANALYSIS \*\*\*  
Based on actual data from OCT 1984 through SEP 1990

8:11 Friday, September 18, 1992 9

CORRELATION ANALYSIS

1 'WITH' Variables: LTDEATHS  
1 'VAR' Variables: FORECAST

Simple Statistics

| Variable | N  | Mean     | Std Dev  | Sum        | Minimum  | Maximum  | Label                 |
|----------|----|----------|----------|------------|----------|----------|-----------------------|
| LTDEATHS | 72 | 2.921216 | 0.607556 | 210.327569 | 1.386294 | 3.970292 |                       |
| FORECAST | 72 | 2.789860 | 0.579206 | 200.869927 | 1.447417 | 3.749011 | Forecast for LTDEATHS |

Pearson Correlation Coefficients / Prob > |R| under Ho: Rho=0 / Number of Observations

FORECAST

|          |         |
|----------|---------|
| LTDEATHS | 0.81136 |
|          | 0.0001  |
|          | 60      |

8:11 Friday, September 18, 1992 10

## Variable=RESIDUAL      Residual: Actual-Forecast

|               |       |
|---------------|-------|
| Missing Value | .     |
| Count         | 24    |
| % Count/Nobs  | 28.57 |



Hence, the following model was estimated from the data with standard errors in parentheses:

$$Z_t = -.101 - .134 I_t + (1 - .854 B^{12}) a_t$$

(.025) (.112) (.381)

The t-values of the trend effect (-.101) and moving average effect of order 12 (.854) reveal statistically significant influences with the one-tailed  $t = -4.05$ ,  $p < .0005$  for the trend. The one-tailed  $t = -1.2$ ,  $p < .15$  indicates a weak intervention effect. The estimated trend parameter reveals an annual decline in operator fatalities of  $1 - e^{-.101} = 9.6\%$ . The value of the intervention parameter indicates an additional decline during the twelve following months of  $1 - e^{-.134} = 12.6\%$ .

The  $R^2 = .658$  (the square of the correlation between LTDEATHS and FORECAST = .81136) and the  $\chi^2 = 20.4$  for 24 lags ( $p = .617$ ) indicates a good model fit, i.e., the lack of autocorrelation (white noise) in the estimated residuals. The normality of the residuals is reflected by the probability (Shapiro-Wilk  $W$ )  $< .942$ . Also the FORECAST LEAD = 12 permits a twelve-month forecast of total number of operators that might be killed, along with the 5% and 95% confidence intervals.

#### HEAD-RELATED FATALITIES

SAS CODE. Similarly, the following SAS code was generated for the ARIMA analysis for the head-related fatality data, with a different model structure:

```
%LET DEPVAR=LHDEATHS;
PROC ARIMA DATA=RESID.MOTOR;
IDENTIFY VAR=&DEPVAR(12) CROSSCOR=(INTER(12)) NLAG=12 NOPRINT;
ESTIMATE P=(12) INPUT=(INTER) NOCONSTANT ML;
```

FORECAST LEAD=12 OUT=AUTO;

RUN;

RESULTS. The code produced the following results:

ARIMA Procedure

Name of variable = LHDEATHS.

Period(s) of Differencing = 12.

Mean of working series = -0.18185

Standard deviation = 0.764024

Number of observations = 60

NOTE: The first 12 observations were eliminated by differencing.

Autocorrelations

| Lag | Covariance | Correlation | -1 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1     | 0    | 1     | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 1 | Std      |
|-----|------------|-------------|----|---|---|---|---|---|---|---|---|-------|------|-------|---|---|---|---|---|---|---|---|---|----------|
| 0   | 0.583733   | 1.00000     |    |   |   |   |   |   |   |   |   |       |      | ***** |   |   |   |   |   |   |   |   |   | 0        |
| 1   | 0.032686   | 0.05599     |    |   |   |   |   |   |   |   |   | .     | *    | .     |   |   |   |   |   |   |   |   |   | 0.129099 |
| 2   | 0.104698   | 0.17936     |    |   |   |   |   |   |   |   |   | .     | **** | .     |   |   |   |   |   |   |   |   |   | 0.129504 |
| 3   | 0.022492   | 0.03853     |    |   |   |   |   |   |   |   |   | .     | *    | .     |   |   |   |   |   |   |   |   |   | 0.133580 |
| 4   | 0.095223   | 0.16313     |    |   |   |   |   |   |   |   |   | .     | ***  | .     |   |   |   |   |   |   |   |   |   | 0.133765 |
| 5   | 0.00064592 | 0.00111     |    |   |   |   |   |   |   |   |   | .     | .    | .     |   |   |   |   |   |   |   |   |   | 0.137040 |
| 6   | 0.045990   | 0.07879     |    |   |   |   |   |   |   |   |   | .     | **   | .     |   |   |   |   |   |   |   |   |   | 0.137040 |
| 7   | 0.086476   | 0.14814     |    |   |   |   |   |   |   |   |   | .     | ***  | .     |   |   |   |   |   |   |   |   |   | 0.137793 |
| 8   | -0.0052479 | -0.00899    |    |   |   |   |   |   |   |   |   | .     | .    | .     |   |   |   |   |   |   |   |   |   | 0.140423 |
| 9   | 0.101561   | 0.17399     |    |   |   |   |   |   |   |   |   | .     | ***  | .     |   |   |   |   |   |   |   |   |   | 0.140432 |
| 10  | -0.018813  | -0.03223    |    |   |   |   |   |   |   |   |   | .     | *    | .     |   |   |   |   |   |   |   |   |   | 0.143980 |
| 11  | 0.071238   | 0.12204     |    |   |   |   |   |   |   |   |   | .     | **   | .     |   |   |   |   |   |   |   |   |   | 0.144100 |
| 12  | -0.271103  | -0.46443    |    |   |   |   |   |   |   |   |   | ***** | .    | .     |   |   |   |   |   |   |   |   |   | 0.145813 |

"," marks two standard errors

Inverse Autocorrelations

| Lag | Correlation | -1 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1   | 0     | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 1 |
|-----|-------------|----|---|---|---|---|---|---|---|---|-----|-------|---|---|---|---|---|---|---|---|---|---|
| 1   | -0.08315    |    |   |   |   |   |   |   |   | . | **  | .     | . |   |   |   |   |   |   |   |   |   |
| 2   | -0.02778    |    |   |   |   |   |   |   |   | . | *   | .     | . |   |   |   |   |   |   |   |   |   |
| 3   | -0.08496    |    |   |   |   |   |   |   |   | . | **  | .     | . |   |   |   |   |   |   |   |   |   |
| 4   | -0.07054    |    |   |   |   |   |   |   |   | . | *   | .     | . |   |   |   |   |   |   |   |   |   |
| 5   | 0.00513     |    |   |   |   |   |   |   |   | . | .   | .     | . |   |   |   |   |   |   |   |   |   |
| 6   | -0.06859    |    |   |   |   |   |   |   |   | . | *   | .     | . |   |   |   |   |   |   |   |   |   |
| 7   | -0.04202    |    |   |   |   |   |   |   |   | . | *   | .     | . |   |   |   |   |   |   |   |   |   |
| 8   | -0.03090    |    |   |   |   |   |   |   |   | . | *   | .     | . |   |   |   |   |   |   |   |   |   |
| 9   | -0.13200    |    |   |   |   |   |   |   |   | . | *** | .     | . |   |   |   |   |   |   |   |   |   |
| 10  | -0.02168    |    |   |   |   |   |   |   |   | . | .   | .     | . |   |   |   |   |   |   |   |   |   |
| 11  | -0.09929    |    |   |   |   |   |   |   |   | . | **  | .     | . |   |   |   |   |   |   |   |   |   |
| 12  | 0.37738     |    |   |   |   |   |   |   |   | . | .   | ***** | . | . |   |   |   |   |   |   |   |   |

ARIMA Procedure

Partial Autocorrelations

| Lag | Correlation | -1 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0     | 1   | 2   | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 1 |
|-----|-------------|----|---|---|---|---|---|---|---|---|---|-------|-----|-----|---|---|---|---|---|---|---|---|
| 1   | 0.05599     |    |   |   |   |   |   |   |   |   |   | *     |     |     |   |   |   |   |   |   |   |   |
| 2   | 0.17678     |    |   |   |   |   |   |   |   |   |   | ****  |     |     |   |   |   |   |   |   |   |   |
| 3   | 0.02109     |    |   |   |   |   |   |   |   |   |   |       | *   |     |   |   |   |   |   |   |   |   |
| 4   | 0.13341     |    |   |   |   |   |   |   |   |   |   |       | *** |     |   |   |   |   |   |   |   |   |
| 5   | -0.02263    |    |   |   |   |   |   |   |   |   |   |       |     | *   |   |   |   |   |   |   |   |   |
| 6   | 0.03195     |    |   |   |   |   |   |   |   |   |   |       |     | *** |   |   |   |   |   |   |   |   |
| 7   | 0.14695     |    |   |   |   |   |   |   |   |   |   |       |     | *   |   |   |   |   |   |   |   |   |
| 8   | -0.06306    |    |   |   |   |   |   |   |   |   | * |       |     |     |   |   |   |   |   |   |   |   |
| 9   | 0.14598     |    |   |   |   |   |   |   |   |   |   |       | *** |     |   |   |   |   |   |   |   |   |
| 10  | -0.06321    |    |   |   |   |   |   |   |   |   | * |       |     |     |   |   |   |   |   |   |   |   |
| 11  | 0.04964     |    |   |   |   |   |   |   |   |   |   | *     |     |     |   |   |   |   |   |   |   |   |
| 12  | -0.49919    |    |   |   |   |   |   |   |   |   |   | ***** |     |     |   |   |   |   |   |   |   |   |

Autocorrelation Check for White Noise

| To  | Chi    | Autocorrelations |       |       |        |       |        |       |        |  |  |
|-----|--------|------------------|-------|-------|--------|-------|--------|-------|--------|--|--|
| Lag | Square | DF               | Prob  |       |        |       |        |       |        |  |  |
| 6   | 4.55   | 6                | 0.602 | 0.056 | 0.179  | 0.039 | 0.163  | 0.001 | 0.079  |  |  |
| 12  | 26.23  | 12               | 0.010 | 0.148 | -0.009 | 0.174 | -0.032 | 0.122 | -0.464 |  |  |

ARIMA Procedure

Maximum Likelihood Estimation

|           |          | Approx.   |         |     |          |       |
|-----------|----------|-----------|---------|-----|----------|-------|
| Parameter | Estimate | Std Error | T Ratio | Lag | Variable | Shift |
| AR1,1     | -0.55751 | 0.11065   | -5.04   | 12  | LHDEATHS | 0     |
| NUM1      | -0.84471 | 0.15833   | -5.34   | 0   | INTER    | 0     |

Variance Estimate = 0.32296578

Std Error Estimate = 0.56830078

AIC = 108.893047

SBC = 113.081735

Number of Residuals = 60

Correlations of the Estimates

| Variable | Parameter | LHDEATHS | INTER |
|----------|-----------|----------|-------|
|          |           | AR1,1    | NUM1  |
| LHDEATHS | AR1,1     | 1.000    | 0.057 |
| INTER    | NUM1      | 0.057    | 1.000 |

Autocorrelation Check of Residuals

|     |        | Chi |       | Autocorrelations |        |        |        |        |        |  |
|-----|--------|-----|-------|------------------|--------|--------|--------|--------|--------|--|
| Lag | Square | DF  | Prob  |                  |        |        |        |        |        |  |
| 6   | 0.84   | 5   | 0.975 | 0.009            | 0.005  | -0.005 | 0.037  | -0.104 | -0.007 |  |
| 12  | 4.93   | 11  | 0.934 | 0.018            | -0.042 | 0.081  | -0.025 | 0.026  | -0.209 |  |
| 18  | 5.99   | 17  | 0.993 | 0.077            | -0.030 | 0.002  | -0.005 | 0.062  | -0.046 |  |
| 24  | 14.86  | 23  | 0.900 | -0.048           | 0.005  | -0.205 | 0.102  | -0.130 | -0.138 |  |

Model for variable LHDEATHS

No mean term in this model.

Period(s) of Differencing = 12.

Autoregressive Factors

Factor 1:  $1 + 0.55751 B^{12}$

Input Number 1 is INTER.

Period(s) of Differencing = 12.

Overall Regression Factor = -0.84471

The following model was estimated for number of motorcycle operators dying from head-related injuries:

$$Z_t = \frac{-.845}{(.112)} I_t + \frac{a_t}{(1 + .558 B^{12})} \quad (.111)$$

The equation reveals a previous finding not shown here that there was no statistically significant decline in head-related deaths prior to the implementation of the law ( $t = -.80$ ). The  $t$ -values of the intervention effect ( $-.845$ ) and autoregressive effect of order 12 ( $-.558$ ) reveal statistically significant influences with the one-tailed  $t = -5.34$ ,  $p < .0005$  for the law's effect.

The value of the intervention parameter indicates a large decline during the twelve months after the law's implementation of  $1 - e^{-.845} = 57.0\%$ . The  $R^2 = .551$  (the square of the correlation between LTDEATHS and FORECAST = .742) and the  $\chi^2 = 14.9$  for 24 lags ( $p = .900$ ) indicates a good model fit; the normality of the residuals is reflected by the probability (Shapiro-Wilk  $W$ )  $< .177$ .

The major difference is the use of the NOCONSTANT options in the ESTIMATE statement, because previous modelling failed to find a secular trend in head-related fatalities prior to the intervention. This was probably caused by the small number of cases involved, thus diminishing the statistical power of the test.

DISCUSSION. In conclusion, SAS/ETS' PROC ARIMA on the PC provides a very economical way to perform the Box-Tiao time-series intervention methodology/transfer function analysis for estimating secular trends before and changes after any type of intervention. The data can easily be modelled according to absolute change or percentage change, as was the case in this analysis. This can be

easily performed with minimal data preparation and few modelling lines of code.

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