Bob Brown

Minister for Land Transport

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REPORT SHOWS ECONOMY IS NOT RESPONSIBLE FOR LOWER ROAD TOLL

A report released today by Federal Land Transport Minister, Bob Brown, shows that most of the 25 per cent drop in road fatalities between 1989 and 1991 was the result of a genuine improvement in road safety.

'The report, *Factors Affecting the Number of Fatal Road Crashes*, shows that the slowdown in economic activity accounted for only about one third of the reduction', Mr Brown said.

'What is clear is that road fatalities, over the long term, have continued to decline despite the level of economic activity and an increasing number of vehicles on Australian roads. This is contrary to a belief held by some that the declining road toll is primarily related to lower fuel sales.'

The study found that fatal crash numbers are also influenced by seasonal factors and that in certain states, such as New South Wales and Queensland, the number of fatal crashes fell as the number of rainy days increased.

'Although the report shows that changes in economic activity can affect levels of road trauma, two points are clear: the number of road fatalities continues to fall, whether in times of high or low economic activity; and the effect of reduced economic activity on the road toll is much less than previously believed', Mr Brown said.

The report, *Factors Affecting the Number of Fatal Road Crashes*, sets out to assess factors which influence the level of road trauma. It was prepared for the Federal Office of Road Safety by the School of Mathematics at the Queensland University of Technology. Copies are available by telephoning (06) 274 7136.

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Factors affecting fatal road crash trends: Summary report.

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Abstract

This report summarises the influence of non-road safety factors on the level of fatal road crashes.

Economic, social and meteorological factors were analysed as independent processes, each capable of influencing the number of fatal crashes. Various statistical models were fitted to determine the power of each factor to predict crash trends.

This report summarises the findings described in report CR 106.

Keywords

Fatal road crash trends; economic factors; social factors; meteorological factors; non-road safety factors; predicting road crash trends.

NOTES:

(1) FORS Research reports are disseminated in the interests of information exchange.

(2) The views expressed are those of the author(s) and do not necessarily represent those of the Commonwealth Government.

(3) The Federal Office of Road Safety publishes four series of research report

(a) reports generated as a result of research done within the FORS are published in the OR series;

(b) reports of research conducted by other organisations on behalf of the FORS are published in the CR series.

(c) reports based on analyses of FORS' statistical data bases are published in the SR series.

(d) minor reports of research conducted by other organisations on behalf of FORS are published in the MR series.

Factors affecting fatal road crash trends:

Summary report (CR109)

This report summarises the results of a study investigating the effects of various non-road safety factors on the level of fatal road crashes. The study took steps to develop equations capable of predicting future levels of fatal road crashes.

N.B. A detailed literature review and the statistical workings from the study are included in the more comprehensive report:

Factors affecting fatal road crash trends (CR106).

Statistical Consulting Unit

Queensland University of Technology

Road Safety Division Research Project 90R2/6/4

Factors Affecting Fatal Road Crash Trends

Summary Report

A.N. Pettitt, M.A. Haynes & S. Low Choy

July 1992

FEDERAL OFFICE OF ROAD SAFETY RESEARCH PROJECT 90R2/6/4 FACTORS AFFECTING FATAL ROAD CRASH TRENDS

EXECUTIVE SUMMARY

- An analysis of fatal road crash numbers over the last decade showed that they were subject to a number of processes.

- There is a general downward trend (on average 40 crashes per year) which could be interpreted as being due to the combined effects of all road safety measures. Within the decade there are periods of little decrease (mid '83 until mid '88) and rapid decrease (early '82 until mid '83; mid '88 until end '91). Within a year there are deviations from the trend with, for example, December's and September's figures generally being the largest.

- In addition to the general decline in crash numbers and the seasonal effects for Australia, it appears that when fuel sales decline then crash numbers also decline. Relating fuel sales to road travel and general economic activity, it appears that economic activity affects crash numbers significantly. For example, it is estimated that for 1990, downward changes in fuel sales explain a reduction in crash numbers equal to 39; for the first three quarters of 1991 this reduction is 132.

- In Queensland crash numbers appear to be influenced by the number of wet days. For an extra 10 rain days per month (a not unlikely change) a reduction equal to 11% of the average number of accidents is suggested. In NSW the effect is less significant and if present 8 extra rain (a not unlikely change) days would reduce the number of accidents by 5.0% of the average number. Plausible reasons for this might be that rain causes a change in driving habits, e.g. slower speeds, and a smaller risk of fatality if a crash occurs. There may be more crashes, but not fatal ones.

- 1990 crash figures were 14.7% less than 1989 figures. According to the model developed, given a continuation of 1989 trends and economic activity into 1990, the 1990 total figure should have been 6.6% less than the 1989 one. Taking into account actual economic activity in 1990 as represented by actual 1990 fuel sales, the model predicts a further drop of 1.7%. The further 6.4% difference between what was predicted and what occurred in 1990 could be explained by additional recessional effects which were not measured by 1990 fuel sales, or by specific road safety measures which were not incorporated in the model. The difference 6.4% is a consistent outcome given the model's error of prediction.

- For the first three quarters of the year, the 1991 crash figures were 21.4% less than the equivalent 1989 figures. According to the model developed, given a continuation of 1989 trends and economic activity into 1990 and 1991, the 1991 figure should have been 13.7% less than the 1989 one. Taking into account actual economic activity in 1991 as represented by actual 1991 fuel sales and actual crash levels in 1990, the model predicts the total number of crashes should have been 24.7% less than the 1989 total. For 1991 figures the recession and other factors have contributed to a 7.7% reduction in crash numbers over what might have been expected given continuing high economic activity of 1989.

- In summary, given a continuation of economic conditions and road safety trends from 1989 to 1990 and 1991, the model predicts reductions of fatal crashes equal to 6.6% and 13.7% of the 1989 figures, for 1990 and 1991 respectively. What occurred were reductions equal to 2.2 and 1.6 times these values for 1990 and 1991 respectively.

- Of the 21.4% reduction from 1989 to 1991, only 7.7%, or just over a third of the reduction, could be attributed to the effects of the recession. The model suggests that if there were to be a return to economic conditions typical of 1989, a 'miniboom', the downward trend in the number of fatal crashes would continue but would be less pronounced than that of late.

BACKGROUND

Statistics on the total number of fatal road crashes are published on a regular basis and these are used to monitor changes in road safety levels.

Although there has been a general decrease in crash numbers over the last 10 to 20 years, there have also been marked variations in these numbers within this period.

It is likely that variations in crash statistics reflect not only advances in road safety (e.g. less drink driving), and random statistical variation, but also the effects of various economic, demographic, and climatic factors.

OBJECTIVES

(a) To develop and evaluate equations designed to:

   (i) provide some degree of explanation of variations in recent fatal crash figures in terms of variables other than those that measure direct road safety initiatives (e.g. general economic, demographic, or climatic factors; and changes in vehicle usage patterns)

   (ii) predict future fatal crash figures

   (iii) allow comparisons of road safety performance to be made between states and territories which control for the differential influence of other factors in those localities.

(b) Estimate the time frame over which useful predictions of future outcomes can be made.

(c) Determine whether observed changes in recent crash numbers lie outside predicted ranges (that is, whether the data provide evidence for the likely action of other factors).

STAGES OF THE PROJECT

(i) Time Series Models

The total number of fatal road crashes each month was published by the Australian Bureau of Statistics (ABS) for Australia, the states and the territories until December 1990 and is currently published by the Federal Office of Road Safety. The quarterly series for Australia is plotted in Figure 1 for the period 1981 until 1991. In Figure 2 a smoothed series is plotted showing three phases, early '81 until late '83, late '83 until mid '88, mid '88 until late '91, of downward, level and then downward trends, respectively. An overall maximum rate (8.97 accidents per day) occurs in December 1985 and a minimum for the period January 1981 to December 1989 occurs in July 1984 (5.42 accidents per day).

The monthly series also shows (illustrated in Volume 2, Appendix A) variable behaviour within years. Overall, in a given year the rates for the months of September and December tend to be high but this is not always so. The reason for the large September figure is not certain but is probably associated with an increased amount of discretionary travel associated with the school holidays.

In this study time series models are used extensively. Time series models try to capture the systematic parts of the series, that is trend and seasonal effects (e.g. monthly effects for monthly data) and also quantify the random variation which cannot be explained. Trends in accident numbers generally tend to be downward due to continuous improvements in road and vehicle safety and driver education. Seasonal effects are obviously due to seasonal weather patterns, daylight changes, holidays, and so on, with timings of holidays being probably the most important factor. Models can be used both for explanatory purposes, as historical data are considered and various characteristics explained, or for predictive purposes where future values are forecast on the basis of current and past data. Different models may be used for explanatory and predictive purposes. For explanatory models other concurrent variables can be used to explain values in the series; for predictive purposes, other concurrent variables may be as difficult or more difficult to predict than the series being studied and so frequently predictive equations are based only on the past values of the series (a so-called pure time series model). Additionally, explanatory models can be used to answer 'what-if' questions, for example what if the price of fuel were to be reduced by, say, 20 percent and obtain projections under these changed conditions, other things being equal.

(ii) Explanatory variables

Previous published longitudinal studies of accident data (see Volume 1), which purport to explain changes in road accident figures, include important explanatory variables in the following classes: economic, driver demographics, vehicle demographics, exposure to road use, climatic and legislation. In this study explanatory variables were sought in each of the classes except legislation.

Examples of variables included in this study in each class are given in the following. Economic variables such as gross domestic product and unemployment measure overall economic activity. Costs that might affect the vehicle user are represented by the consumer price index, the consumer price index for transport, price and changes in price of fuel or petrol. Vehicle stock is represented by new, recent and total vehicle registrations. Weather is represented by the number of rain days. A measure of vehicle usage (vehicle kilometres travelled) which can be used for monthly or quarterly modelling is not available in

Australia. Instead, sales of fuel for road transport purposes can be used.

Alcohol is known to be a factor in many crashes, but from a level of aggregation equal to Australia or states on an annual basis, alcohol consumption does not appear to be a useful variable. In some Australian reports, a suggestion is made that consumer sentiment correlates well with fatal crashes. This was investigated and consumer sentiment was found to have no significant statistical association with the number of fatal crashes.

Some variables were sought but not readily available while other variables were available but were not used in the formal statistical analysis of the study because there was little evidence of their likely usefulness (**Volume 2, Appendix B**). In the table below we give details of these variables.

List of Variables Considered but not Formally Tested

Variable	Reason
Consumer Price Index	Steady trend only; useful for obtaining real prices
Consumer Price Index for Transportation Group	Steady trend only
Gross Domestic Product	National only
Resident Population Estimates	Used for standardisation to obtain accident rates
Annual Estimated Resident Population by Age Groups and Gender	Steady trend only
Sales of LPG fuel for automotive use	Useful for aggregate fuel sales, but only small component thereof
Number of driver licences in force	Only available for WA
Vehicle kilometres travelled	Available at 3 year intervals only
Alcohol consumpution	Annual data only and steady aggregated consumption

In order to make comparisons between Australia and the states, only those variables which were available for all states and territories were used in the study. The variables which we used in the study and found to be useful were unemployment rate, price of vehicle fuel, new vehicle registrations, index of rain days per month, sales (in volume) of fuel for transport.

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In the table below we summarise the findings.

LIST OF VARIABLES FORMALLY TESTED AND RESULTS	
Variable Tested	**Result**
Available monthly and tested monthly	
Unemployment (and lagged terms)	Not significant: National and States
New motor vehicle registrations (and lagged terms)	Not significant: National and States
Sales of automotive gasoline (and lagged terms)	Significant: National Not significant: States
Sales of inland automotive diesel	Not significant: National and States
Number of rain days	Significant: Queensland Marginally significant: NSW Not significant: Victoria Not appropriate: National
Consumer Sentiment	Not significant: National and Queensland
Available quarterly only	
Change in retail petrol prices	Not significant: National and States
Available monthly and tested quarterly	
Unemployment	Not significant: National and States
New motor vehicle registrations	Not significant: National and States
Sales of automotive gasoline	Significant: National & Victoria Not significant: Queensland & NSW
Sales of inland automotive diesel	Not significant: National and States
Consumer Sentiment	Not significant: National and Queensland

(iii) Models involving Explanatory Variables

Statistical models for the series of numbers of fatal road crashes involving explanatory variables were developed using the following methodology. The trend and seasonal aspects of the series were explicitly modelled by allowing them to vary with time rather than keeping these aspects fixed over the period of study. This allows, for example, for a trend to be modelled by an equation which more closely follows the local behaviour of the data than a straight line or quadratic curve fitted to the data for the complete period.

Having modelled these aspects explicitly, data for the various explanatory variables were entered into the model, both individually and in groups, to investigate whether the effects of the variables were significant and constant over time. If this were the case, then further statistical models were fitted to the data to obtain predictive models. Thus the first stage determines whether particular variables do explain the series after allowance for trends and seasonal effects has been made, and the second stage uses significant results to obtain predictive equations. **(Volume 2, § 5)**

(iv) Prediction Equations for Crashes and Fatalities

A simple method for obtaining predictions for the number of fatalities is to take a prediction for the number of fatal crashes and multiply this by a prediction for the number of fatalities per crash.

The prediction for the number of fatalities per crash can take into account variations due to state or territory and month of the year. **(Volume 2, §9)**.

RESULTS

(i) Time Series Models for Fatal Crashes

Time series models involving no explanatory variables were fitted to the monthly data for predictive purposes for the Australia and states series. Trends and seasonal variations are removed from the series so obtaining a derived series of first differences and seasonal differences by month. The derived series is then modelled to allow for the associations present between lagged values.

Time series models were fitted to the monthly number of fatal road crashes series for Australia and the states. **(Volume 2; § 3)**. For all series, it was found that the so-called time series ARIMA 'airline' model, one of a range of models which allow for trend, seasonal effects and error, provided a good fit to the data. For Australia and NSW, the data for the period March 1983 to December 1990 was used, whereas for other states, the period January 1976 until December 1990 was used. For the NSW series (and consequently Australia series) there is an apparent large change in values around February 1983 when there was a substantial drop in the general level of the series. It would be wise to model NSW and Australia data using only those data from March 1983, as was done, for time series modelling. There was a large amount of similarity between estimated parameter values for the 'airline' models fitted to the Australia and states series although the series themselves are very different. **(Volume 2; Table 4.1)**. The models were used to predict values for January 1991 to December 1991 using data up to December 1990 as a base. Predictions were compared with actual values. Prediction errors were consistent with the inherent variability which is to be expected in monthly counts such as the number of fatal accidents. That is, the prediction model was performing as well as any prediction model could perform. **(Volume 2; Table 4.3; § 4.4)**.

(ii) Explanatory Models for Fatal Crashes

Statistical time series models involving explanatory variables were developed to explain the variation in the numbers of fatal crashes in the last 10 years. Data for Australia, the states and the territories were considered. Monthly and quarterly series were considered; quarterly data were standardised by population estimates to facilitate comparisons across states. Only significant effects are reported. Many more relationships were investigated but they were not found to be significant. **(Volume 2; Tables 7.1, 7.3, 7.5, 7.6)**.
Australia

For **Quarterly** data, sales, by kilolitre, of automotive gasoline (fuel sales) was found to be significant when fitted to data 2nd quarter 1981 to 4th quarter 1989. For data from 2nd quarter 1981 to 4th quarter 1990, the effect remained significant **(Table 7.1, § 8.2)**. The relationship between accident rates and fuel sales was constant over the period of investigation. Note that the period in early 1983 when a substantial drop was observed is included in the fitting process so allowing the explanatory model to explain this drop.

For the most recently fitted model, the regression coefficient for fuel sales is 2.78×10^{-4} accidents per quarter per kilolitre fuel sales. (**Volume 2; Table 8.4a**). Recent values of fuel sales are about 4.3×10^6 kilolitres per quarter. The relationship between crash numbers and fuel has been steady over the period 1983 - 1990. The model first allows for trend and seasonal effects and then takes account of fuel sales. The model fitted to the quarterly count of fatal road crashes (NFC), is

$$\nabla \text{NFC} = -9.5 + \nabla \text{Q2} \times (-12.4)$$

$$+ \nabla \text{Q3} \times 12.6 + \nabla \text{Q4} \times 21.2$$

$$+ \nabla \text{FUEL} \times 2.78 \times 10^{-4}$$

(Volume 2; § 8.2)

where ∇ refers to the first difference of the series $(y_t - y_{t-1})$ and Q2, Q3 and Q4 are indicators for the 2nd, 3rd and 4th quarters respectively; (**Volume 2; § 8.2**). Thus ∇Q2 takes the value 1 (1 - 0) for second quarter and - 1 (0 - 1) for the third quarter, and zero for the first and fourth quarters; similar remarks hold for ∇Q3 and ∇Q4. FUEL is the quarterly fuel sales in kilolitres. Thus a change, from one quarter to the next, in fuel equal to 4×10^5, about 10 percent of the average value of quarterly fuel sales, is predicted by the model to give a change, from one quarter to the next, of $2.78 \times 10^{-4} \times 4 \times 10^5$ or 111 crashes. The average quarterly count has been about 450 crashes, so the change in crashes is about 25% of the average. Changes in 1991 in fuel have been less than 4.3×10^5 and in 1989 and 1990 less than 1.2×10^5 except in 4th quarter 1990 when it was 23×10^5. In Figure 3 quarterly fuel sales and quarterly crash numbers are graphed together. In Figure 4, values of ∇NFC and ∇FUEL are plotted together against time and it can be seen that the two series are highly related, although it must be emphasised that the seasonal effects have not been removed from the two series. In Figure 5 a plot, ignoring the time sequence, of ∇NFC values against ∇FUEL values is given and a strong linear relationship is shown.

In this analysis, fuel sales are taken as the proxy for economic activity. From Figure 3, it can be seen that fuel sales climbed steadily through the period of the study until 4th quarter 1989, 1990 figures looked very much like 1989 figures, with no growth from the 1989 base experienced. The 1991 figures showed a considerable drop from 1990 figures, with the 3rd quarter 1991 figure below the 3rd quarter 1988 figure. In the context of fuel sales, a return in 1992 to values typical of 1989 could be classified as 'miniboom' economic conditions.

New South Wales

For **Monthly** data, the NSW weather index (number of rain days per month averaged over the State by centres of population) was found to be marginally significant with the regression parameter estimated to be -1.0×10^{-2} accidents per day per rain day per month. (**Volume 2; Table 6.3, 6.4; § 6.2**). For an increase of 8 rain days in a month compared with the previous month, the effect of this variable would be to reduce accidents by 0.08 per day compared with the previous month or about 5.0 percent of a recent average (1.6 accidents per day per month). The number of rain days per month has generally been in the range 10.69 ± 4.05 with exceedances over 16 rain days per month occurring infrequently except in 1989 and 1990. Also values below 4 rain days per month occur infrequently. In 1989, 1990, monthly changes in rain days exceeded 8 in 4 months out of 24. (**Volume 2; Appendix A; Table A.3**). It should be noted that the relationship between fatal crashes and rain days may be due to the concurrence of two unusually wet years, 1989 and 1990, with the reduction in level of crashes also seen in 1989 and 1990 in NSW. That is, the relationship may be due to the spurious occurrence of wet years at a time of a reduction in the number of fatal accidents. If there is indeed an effect from raindays, then its size is unlikely to exceed 5 percent of the average.

Victoria

For **Quarterly** data, the variable fuel sales was found to be significant and the relationship constant over the period of fitting, 2nd quarter 1981 until 4th quarter 1990. When standardised by population, the coefficient takes a similar value to that for the Australia series. (**Volume 2; Tables 7.3, 7.4; § 7.3**).

Queensland

For **Monthly** data, the weather index was found to be marginally significant with regression coefficient estimated to be -1.1×10^{-2} accidents per day per rain day per month. The absolute size of this effect is almost the same as for NSW (-1.1×10^{-2} vs -1.0×10^{-2}) but because the average number of fatal crashes for Queensland is smaller than NSW (0.90 vs 1.6 accidents per day) this effect is relatively more important. For an extra 10 rain days in a month, which is not unlikely, this corresponds to a reduction of 0.10 accidents per day which can be compared with the average of 0.90 accidents per day. Thus, for Queensland, the weather in the form of rain days appears to have a significant effect with an increase of 10 rain days reducing accidents by 11 percent of the average. The number of rain days per month is generally in the range 10.30 ± 4.20 with exceedances over 20 rain days per month and values below 3 rain days per month being unusual. Unlike NSW, the years 1989 and 1990 were not unusually wet and the weather effect appears to be sustained during the period of study, that is the effect is not just the result of chance relationships and should be sustained in the future. (**Volume 2; § 6.4, 6.5; Tables 6.8, 6.9; Appendix A**).

(iii) Prediction Equations for Crashes and Fatalities

On average for Australia over the period April 1975 to December 1989 there are 1.129 fatalities per fatal crash. There appears to be no discernable time trends but there are statistically significant monthly effects. December has a high value, 1.158, significantly different from the others, while July, 1.104, has a significantly low value. Note also that in a given year, December also tends to have the largest number of fatal crashes. States and territories appear similar in their average values except that the ACT has a value, 1.08, significantly lower than the others. (**Volume 2; § 9**).

HOW TO OBTAIN PREDICTIONS

All computations in the study were carried out using commercially available software. Two programs are required to obtain analyses and predictions. These are BATS (Bayesian Analysis of Time Series; West, Harrison and Pole, 1987, Warwick University, U.K.) and GENSTAT (Payne *et al*, GENSTAT 5 Reference Manual, Oxford, 1987). The BATS package fits a model with explicit trend and seasonal factors and allows for the relationship between an explanatory variable and accident numbers to be investigated for different times. This package was used in the first stage of the analysis to find explanatory models. The second stage of the analysis was to obtain predictive models using the GENSTAT package using the explanatory variables.

PRACTICAL IMPLICATIONS

Time Series Models and Predictions

For prediction purposes the technique described above that explicitly removes both trend and seasonal components from the model can be used. So, although the Australia and states series for fatal crashes have different trends and, to a lesser extent, seasonal components, a similar model can be used for predictive purposes for the Australia and states series. Models were fitted to monthly data to produce monthly and quarterly predictions. **(Volume 2; § 2 and 3)**.

When used to predict fatal crash numbers for each month of 1991, this model and similar ones, gave errors of prediction which were consistent with the supposed inherent unpredictability in the occurrence of events such as accidents. That is errors were equal to about $\sqrt{N}$ where N is the number of accidents in the given month. However, there were some systematic differences between predictions and actual values. These included over prediction for Australia and all States except Tasmania for June 1991 and over prediction for the months April, May and June 1991 for Victoria. **(Volume 2; § 4; Table 4.3)**.

For the monthly predictions aggregated to a quarterly level for 1991, the Australia model gave errors of prediction having relative error about 2 percent, i.e. 12 crashes per quarter compared with an average of 450 crashes per quarter for 1991. These errors of prediction for the first two quarters of 1991 are somewhat better than might be expected from the inherent unpredictability of the occurrence of crashes; this error would correspond to 22 crashes for a quarterly total of 450. **(Volume 2; § 8.4, 8.5)**.

Predictions can be made for any number of months ahead from any baseline, but predictions for more than twelve months ahead would be somewhat unreliable. Below we give time series model predictions for daily accident rates for Australia and 95% confidence limits for the predictions. These predictions are based on data up to the end of 1990. Monthly counts are obtained by multiplying the daily rate by the number of days in the month. (Looking at daily rates removes effects of varying month lengths). If the actual value were to lie outside the confidence limits on the same side for two months out of the twelve we would be fairly certain that there had been a significant new effect. **(Volume 2; § 2)**.

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NUMBER OF FATAL ROAD CRASHES FOR AUSTRALIA

Predicted values & 95% confidence limits for 1991
using data up to end 1990
(Units: average daily number of fatal road crashes)

month	predicted	confidence	limits	actual*	error
January	4.63	3.29	5.97	157/31 = 5.06	0.43
February	4.87	3.50	6.27	137/28 = 4.89	0.02
March	5.70	4.27	7.11	170/31 = 5.48	- 0.22
April	4.63	3.16	6.10	156/30 = 5.20	0.53
May	4.91	3.40	6.41	150/31 = 4.84	0.07
June	5.31	3.77	6.85	138/30 = 4.60	- 0.71
July	5.02	3.44	6.60	163/31 = 5.26	0.24
August	4.77	3.15	6.38	171.31 = 5.52	0.75
September	5.92	4.27	7.57	161/30 = 5.37	- 0.55
October	4.91	3.23	6.60	166/31 = 5.35	0.44
November	5.03	3.31	6.75	148/30 = 4.93	- 0.10
December	5.76	4.01	7.52	159/31 = 5.13	- 0.67

average |error| = 0.34

* obtained January 1992 from FORS

The monthly time series approach to prediction provides a one month ahead forecast with an expected error of 0.7 accidents per day for forecasts of monthly average daily accident rates; for predictions twelve months ahead, the expected error increases to 0.9 accidents per day. Monthly average daily rates tend to be about 5 accidents per day so in relative terms these errors are respectively about 14 percent and 18 percent.

Conclusion: Time series predictions up to twelve months ahead provide expected values based on past history and therefore provide control limits. Monthly predictions can be aggregated to provide predictions for longer periods than a month.

Explanatory Models & Predictions

For the Australian quarterly series, fuel sales was found to be a significant explanatory variable. The model suggests that a change in fuel sales equal to 10 percent of the average quarterly value produces a change in fatal crashes equal to about 25 percent of the average quarterly value. (**Volume 2; § 7.2, 8.2**).

Predictions using fuel sales for 1990 can be made in various ways. They can be made using predictions of fuel sales for 1990 based on historical data up to the end of 1989; this basically extrapolates for 1990 the non-recession economic conditions existing through the 80s to the end of 1989. Predictions can be made using actual fuel sales values for 1990; this reflects to some extent the economic conditions existing in 1990 but fuel sales for 1990 are atypical due to the Gulf crisis. Predictions can be compared with actual accident numbers. Doing this gives the following table with various predictions expressed as percentages of the actual figure for 1989.

1990 actual crashes	85.3%	(2049)
1990 prediction using actual 1990 fuel sales	91.7%	(2203)
1990 prediction using 1989 fuel sales	93.4%	(2243)
1989 actual crashes	100%	(2402)

The drop 100 - 93.4 or 6.6% is what might have been expected given continuing 1989 economic conditions and road safety trends into 1990. What occurred was a further drop 93.4 - 85.3 or 8.1% of which 93.4 - 91.7 or 1.7% is explained by the model in terms of the actual economic conditions existing in 1990. The further 91.7 - 85.3 or 6.4% difference between what was predicted for and what occurred in 1990 could be explained by additional economic effects which were not measured by 1990 fuel sales or by specific road safety measures which were not incorporated in the model.

Carrying out a similar analysis for the first three quarters of 1991 using the 1990 accident data as a base we obtain

1991 actual crashes	78.6%	(1404)
1991 prediction using actual 1991 fuel sales	75.3%	(1344)
1991 prediction using 1989 fuel sales	82.6%	(1475)
1989 actual crashes	100%	(1786)

In this case the model predictions using actual fuel sales under predict. The model suggests that the 1991 total is better than if 1989 economic conditions had continued.

Finally we can consider predictions for 1991 using data up to the end of 1989, fuel sales for 1990 and 1991 equal to the values of fuel sales for 1989. These predictions for 1991 represent continuing economic conditions of 1989 and road safety trends of 1989. The predictions are

1st Quarter	**2nd Quarter**	**3rd Quarter**	**Total**
516	505	520	1541

as a percentage of 1989 figure, the total, 1541, is 86.3% whereas, as above, the actual for 1991 is 1403 or 78.6% of the 1989 corresponding total.

We now have various predictions for 1991 (1st quarter - 3rd quarter) as follows

Base 1989, fuel sales = 1989	86.3%
Base 1990, fuel sales = 1989	82.6%
Base 1990, fuel sales = actual	75.3%
Actual 1991 crashes	78.6%.

The drop 100 - 86.3 or 13.7% is what might have been expected given continuing economic activity and road safety trends from 1989. The further drop 86.3 - 82.6 or 3.7% could represent new road safety trends based on 1990 trends. The difference 82.6 - 75.3 or 7.3% is the further drop which would have been expected due to actual economic conditions and predicted by the model. In reality the drop was 82.6 - 78.6 or 4%. The difference 86.3 - 78.6 or 7.7% is the difference between what was predicted for 1991 given the economic and road safety trends of 1989 and what actually occurred. **(Volume 2; § 8.8)**.

Conclusion: Explanatory models are useful for describing past behaviour of the series in terms of other variables. For Australia, a significant relationship involving fuel sales is found. Fuel sales could be taken as a substitute for vehicle kilometres travelled, a variable which is not measured in Australia on a frequent and reliable basis. This relationship can be used to examine the effect of continuing strong economic activity and weak activity on accident numbers.

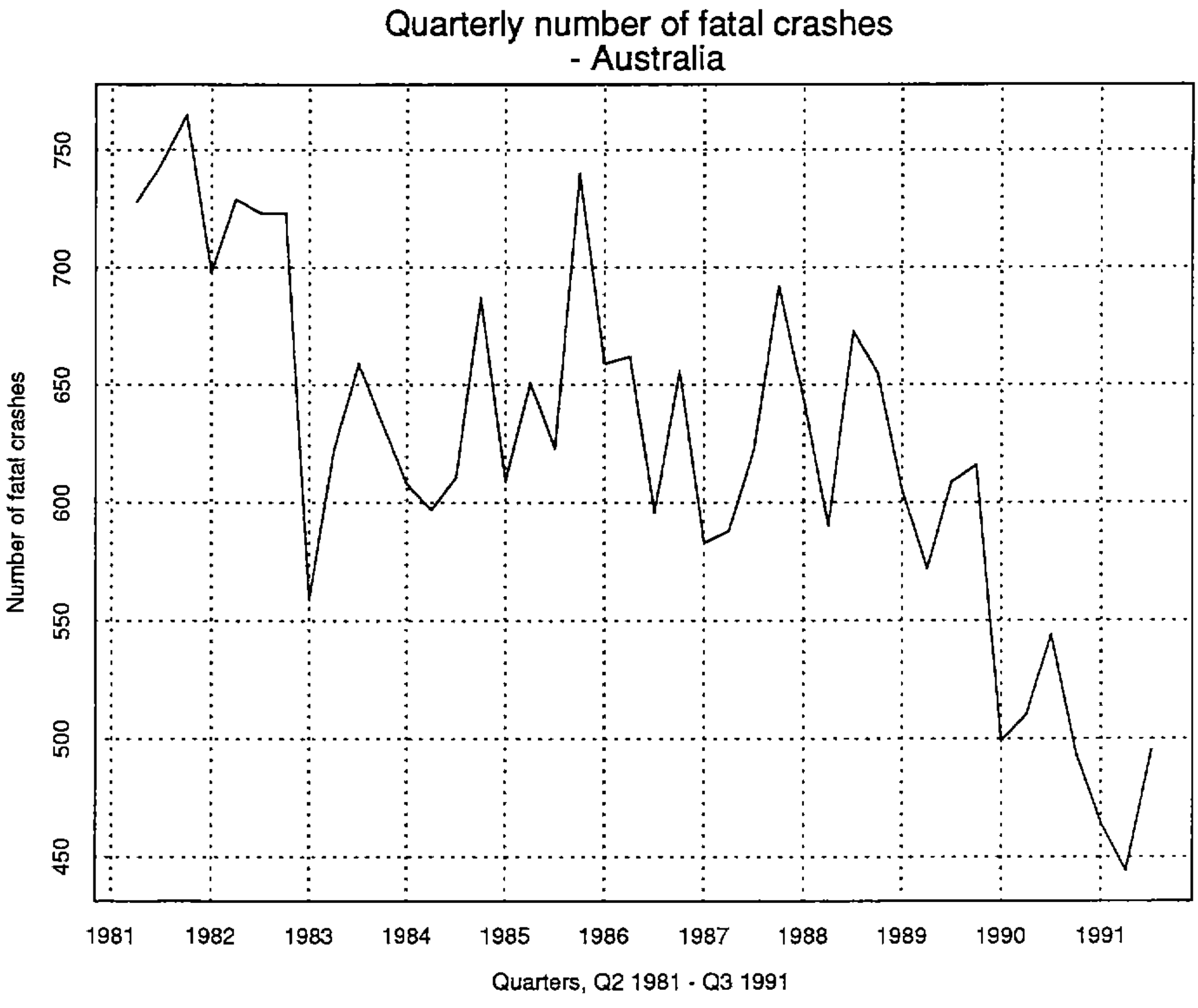

Quarterly number of fatal crashes
- Australia
Number of fatal crashes
450
500
550
600
650
700
750
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
Quarters, Q2 1981 - Q3 1991

Figure 1

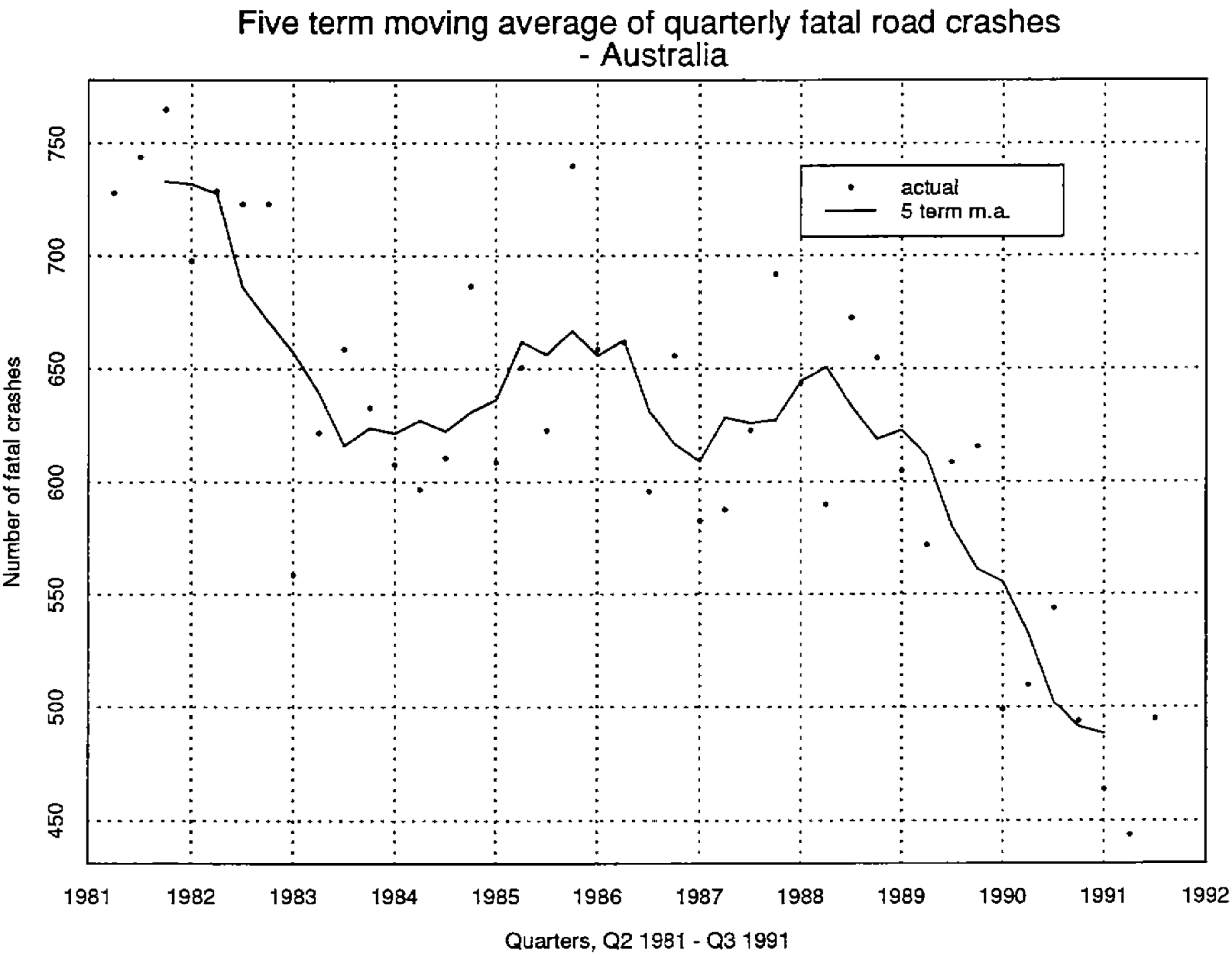
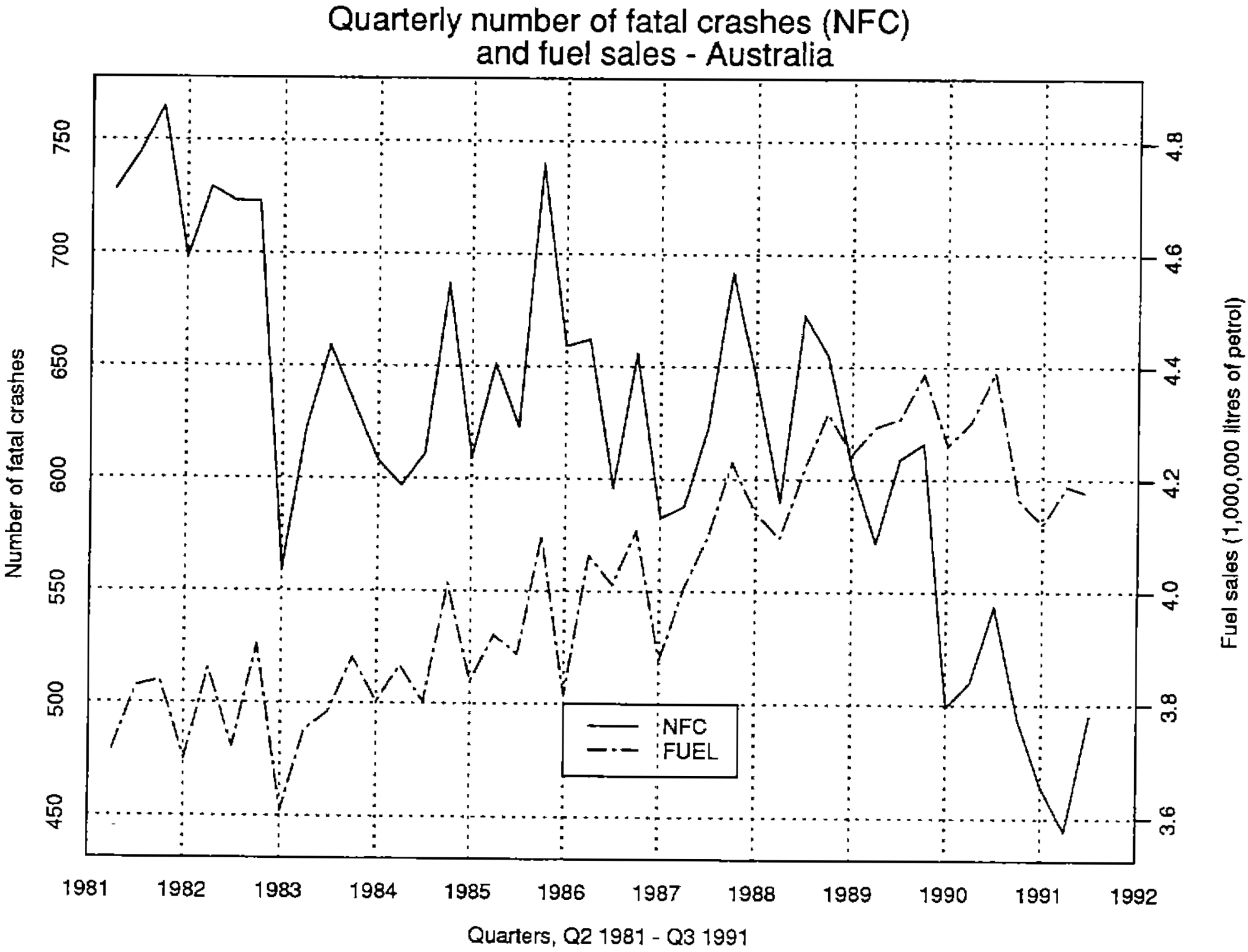
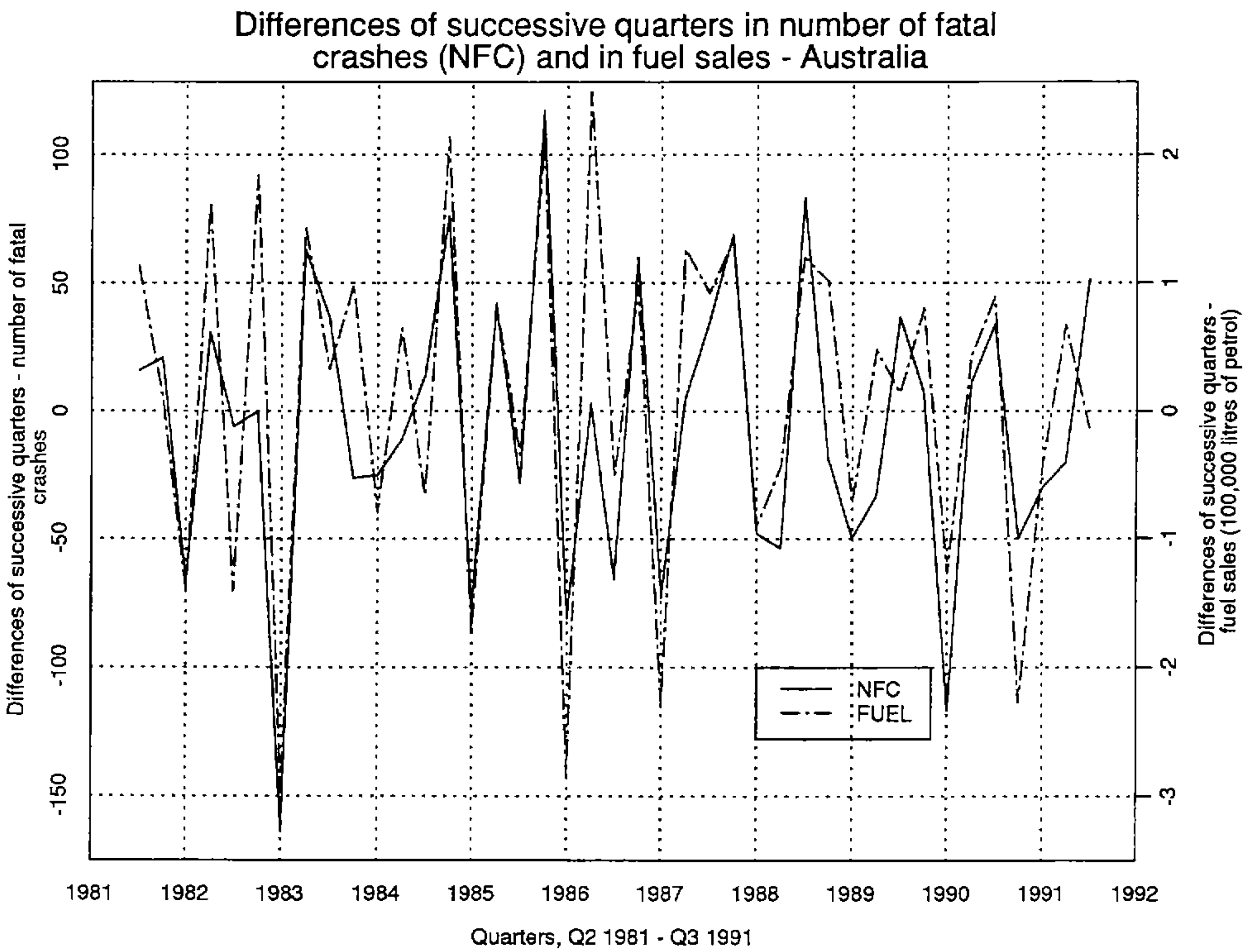

Five term moving average of quarterly fatal road crashes
- Australia
actual
5 term m.a.
Number of fatal crashes
450
500
550
600
650
700
750
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
Quarters, Q2 1981 - Q3 1991

Figure 2



Quarterly number of fatal crashes (NFC) and fuel sales - Australia
Number of fatal crashes
450
500
550
600
650
700
750
Fuel sales (1,000,000 litres of petrol)
3.6
3.8
4.0
4.2
4.4
4.6
4.8
NFC
FUEL
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
Quarters, Q2 1981 - Q3 1991

Figure 3



Differences of successive quarters in number of fatal crashes (NFC) and in fuel sales - Australia
Differences of successive quarters - number of fatal crashes
Differences of successive quarters - fuel sales (100,000 litres of petrol)
Quarters, Q2 1981 - Q3 1991
NFC
FUEL
100
50
0
-50
-100
-150
2
1
0
-1
-2
-3
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992

Figure 4

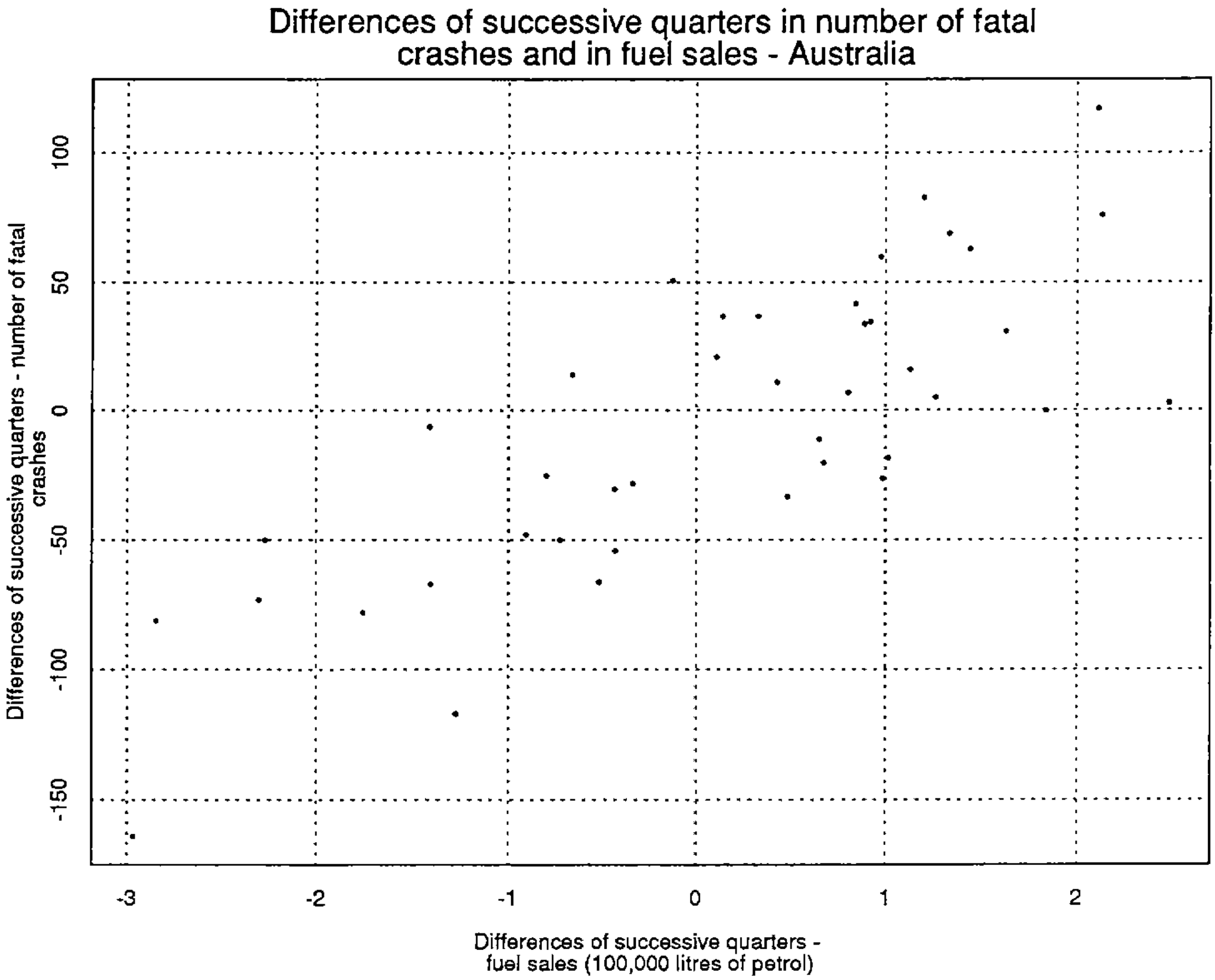

Differences of successive quarters in number of fatal crashes and in fuel sales - Australia
Differences of successive quarters - number of fatal crashes
100
50
0
-50
-100
-150
-3
-2
-1
0
1
2
Differences of successive quarters - fuel sales (100,000 litres of petrol)

Figure 5