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EFFECTS OF MANDATORY SEAT BELT LAWS ON TRAFFIC FATALITIES IN THE FIRST EIGHT STATES ENACTING SEAT BELT LAWS

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16. Abstract

We examined state-specific and aggregate effects of U.S. legislation requiring the use of seat belts among front-seat motor vehicle occupants. Effects of compulsory seat belt use on the number of occupants fatally injured in traffic crashes were examined in the first eight states adopting such laws.

Monthly data on crash fatalities between January 1976 and June 1986 were analyzed using Box-Jenkins intervention analysis time-series methods. Because the new laws apply only to front-seat occupants, front-seat occupant fatalities were compared with: (1) rear-seat fatalities; (2) nonoccupant fatalities (motorcyclists, pedalcyclists, pedestrians); and (3) fatalities among front-seat occupants in neighboring states without compulsory seat belt use. Exposure to risk of crash involvement was controlled by analyzing fatality rates per vehicle mile traveled.

Results revealed a statistically significant decline in the rate of front-seat fatalities of 8.7% in the first eight states with seat belt laws. The fatality rate declined 9.9% in states with primary enforcement laws and 6.8% in states limited to secondary enforcement only. Rates of rear-seat and nonoccupant fatalities have not changed since the belt laws were implemented.

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1 INTRODUCTION

Laws requiring the use of seat belts were first implemented in Australia in 1971, and spread to a number of European countries, Canadian provinces, and other jurisdictions in the subsequent decade. In the mid-1980s, selected states in the United States implemented compulsory belt use laws. The objective of this study was to evaluate the effects of belt laws on motor vehicle fatality rates in the first eight U.S. states implementing such laws.

Numerous studies have found increased belt use and reduced rates of traffic fatalities following implementation of compulsory belt use laws. Although effects varied, rates of seat belt use have typically doubled or tripled immediately after belt laws took effect, both in the United States (Table 1.1), and in other countries (Table 1.2). After immediate dramatic increases in belt use at the time belt laws first took effect, many jurisdictions experienced some decay in use over the subsequent months or years. Estimated fatality reductions following implementation of compulsory belt use vary widely from country to country (from 0 to 80%; Table 1.3). Within the United States, preliminary estimates of the effect of belt laws on fatalities cluster much more narrowly in the range of 1 to 20% (Table 1.4). Many of these studies, especially the earlier ones, used non-random samples, inadequate control groups, and unreported analytic methods.

Table 1.1
EFFECTS OF U.S. SEAT BELT LAWS ON RESTRAINT USE

Source	Jurisdiction	Effective Month	Month Observed	Use Rate
Rood & Kraichy (1985)	NY	12/84	10/84	16%
			4/85	57%
			9/85	46%
Williams & others (1986)	NY	12/84	1/85	69%
			4/85	60%
			2/86	44%
Pace & others (1986)	NY	12/84	4/85	63%
			4&7/86	37%
Brick & others cited in Williams & others (1986)	NJ	3/85		18%
			7/85	40%
Williams & others (1986)	NJ	3/85	11/84	16%
			3/85	51%
			7/85	44%
			4/86	38%
Mortimer (1986)	IL	7/85	4/85	16%
			7/85	40%
			12/85	35% (Drivers)
			1/86	29%
			3/86	32%
			6/86	34%
Wagenaar & others (1987a)	MI	7/85	12/84	18%
			4/85	25%
			7/85	61%
			12/85	44%
			4/86	44%
			7/86	47%
			12/86	44%
Hatfield & others (1985)	TX	9/85	1-6/85	15%
Bunch & others (1986)	TX	9/85	1-6/86	66%
Dept. of Highways (cited in Campbell & others, 1986)	TX	9/85	3/86	75%
Office of Highway Safety (cited in Campbell & others, 1986)	NE	9/85	11/85	26%
			11/85	44%
			2/86	38%
IIHS (1987)	NE	9/85	2/87	29%
Missouri Safety Center (cited in Campbell & others, 1986)	MO	10/85	7/85	12%
			10/85	19%
Campbell & others (1986)	NC	10/85	9/85	25%
			11/85	44%
			1/86	42%
			3/86	45%
			5/86	48%
IIHS (1987)	NC	10/85	2/87	78%

Table 1.2
EFFECTS OF NON-U.S. SEAT BELT LAWS ON RESTRAINT USE[1]

Source	Jurisdiction	Effective Month	Month/Year Observed	Use Rate	Comments
Vulcan (1977)	Australia-Victoria	12/70	5/71	32-48%	Front seat occupants
			2/72	47-60%	
			2/73	52-65%	
			2/74	67-79%	
			2/75	73-79%	
			2/76	73-88%	
Joubert (1979)	Victoria	12/70	pre-law	18%	Observation date not cited
			post-law	64%	Rural
			post-law	75%	Urban
Manders (1984)	Melbourne	12/70	11/82	95%	Drivers
			3/84	96%	Drivers
Johinke (1977)	Adelaide South Australia	12/71	10/71	23%	Occupants with belts available
			10/72	78%	
			10/75	66%	
			mid '76	84%	
Crinion & others (1975)	Adelaide S.A.	12/71	10/64	8%	All seating positions
			10/70	14%	
			10/71	23%	
			10/72	78%	
Road Traffic Bd. (1983)	Adelaide S.A.	12/71	11/82	91%	Drivers
			11/82	85%	Ft-seat pass
			11/82	61%	Rr-seat pass
Seeney (1977)	Queensland	1/72	12/72	90%	
Schnerring (1983)	New South Wales-Sydney Metro	10/71	4/71	30%	Drivers
			10/71	60%	Drivers
			11/71	76%	Drivers
			12/72	89%	Drivers
			12/73	91%	Drivers
			7/75	91%	Drivers
			7/77	91%	Drivers
			7/79	89%	Drivers
			7/81	84%	Drivers
Marburger (1986)	Austria	7/76	pre-law	5-10%	Urban
			pre-law	20-25%	Rural
			post-law	10-15%	Urban
			post-law	40%	Urban
			9/84	81%	Urban
			9/84	82%	Rural
			8/85	81%	Urban
			8/85	82%	Rural
Fisher (1980)	Belgium	6/75	pre-law	17%	
			post-law	87%	
Marburger (1986)	Belgium	6/75	11/84	70%	Rural
			11/84	60%	Urban
Rockerbie (1983)	Canada-British Columbia	10/77	pre-law	20-24%	
			post-law	50%	

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1. Drivers and front-seat passengers unless otherwise noted.

Table 1.2 continued

Source	Jurisdiction	Effective Month	Month/Year Observed	Use Rate	Comments
B.C. Research (1983)	British Columbia	10/77	4/83 6/83	55% 67%	
Arora (1985)	British Columbia	10/77	11/83	67%	
Arora (1985)	New Brunswick	9/83	11/82 11/83	4% 66%	Drivers Drivers
N.B. Dept Transp. (1984)	New Brunswick	9/83	8/84	73%	
Arora (1982)	Newfoundland	7/82	11/81 11/82	9% 68%	
Arora (1985)	Newfoundland	7/82	11/83 11/83	76% 61%	Urban Rural
Murray (1984)	Newfoundland	7/82	7/84	74%	
Arora (1985)	Manitoba	1/84	11/83 11/84	11% 62%	
DataCom (1984)	Manitoba	1/84	6/84	79%	Drivers
Snow (1979)	Ontario	1/76	12/75 2/76 6/76	21% 77% 50%	
Pierce (1979)	Ontario	1/76	5/77 5/78	50% 65%	Increased enforcement mid-77
Mathews (1982)	Ontario	1/76	9-12/80	49%	
Arora (1985)	Ontario	1/76	11/82 11/83	49% 60%	
Jonah & Lawson (1986)	Ontario	1/76	5/84	70%	
Stulginskas & Pless (1983)	Montreal	8/76	5-6/76 5-6/77 5-6/78 5-6/81	15% 33% 45% 56%	Drivers Drivers Drivers Drivers
Arora (1985)	Quebec	8/76	11/82 11/83	68% 60%	Drivers Drivers
Regie de l'assurance Automobile du Quebec in Jonah & Lawson (1986)	Quebec	8/76	6/83	60% 74%	Urban Drivers Freeway Drivers
Simpson & Warren (1981)	Saskatchewan	7/77	pre-law post-law	26% 78%	Drivers Drivers
Sheils (1978)	Saskatchewan	7/77	5/77 7/77 10/77 5/78	24% 65% 73% 60%	

Table 1.2 continued

Source	Jurisdiction	Effective Month	Month/Year Observed	Use Rate	Comments
Bergen & others (1979)	Saskatchewan	7/77	7/77	52%	Drivers
			10/77	70%	Drivers
			5/78	55%	Drivers
			5/79	70%	Drivers
Arora (1982,1985)	Saskatchewan	7/77	11/80	56%	Drivers
			11/81	49%	Drivers
			11/82	48%	Drivers
			11/83	54%	Drivers
Marburger (1986)	Denmark	1/76	pre-law	19%	
			post-law	74%	
Ashton & others (1983)	England	2/83	1/83	43%	
			5/83	95%	
Mackay (1984a,1984b)	England	2/83	2/83	90%	
Oranen (1977)	Finland	7/75	pre-law	15-20%	
			6/75	30%	Highway
			6/75	9%	Urban
			8/75	68%	Highway
			8/75	53%	Urban
			7/76	64%	Highway
			8/76	37%	Urban
Berard-Andersen in Fisher (1980)	Finland	7/75	pre-law	8%	Urban
			pre-law	31%	Rural
			post-law	38%	Urban
			post-law	66%	Rural
Oranen and Koivurova (1977)	Finland	7/75	8-9/78	71%	Highways
			8-9/78	41%	Urban
Marburger (1986)	Finland	7/75	4/82	87%	Urban
			4/82	86%	Rural
			9/83	82%	Urban
			9/83	92%	Rural
Fisher (1980)	France	7/73	pre-law	20-25%	
			7/73	80%	
			10/73	50%	
Chodkiewicz & Dubarry (1977)	France	7/73	1972	20%	
			1973	26%	
			1974	67%	
			1975	80%	
Gerondeau (1979)	France	7/73	7/73	80%	Law applied
			11/73	50%	to rural only
			early '74	80%	
			1979	70-75%	
Gerondeau (1981)	France	7/73	1974	54%	Law applied
			1975	76%	to rural only
			1976	79%	
			1977	72%	
			1978	67%	Law expanded
			1979	69%	to all rds
			1980	79%	in 10/79
Hartemann & Others (1984)	France	7/73	1982	95%	Highways
			1982	75%	Other non-urban

Table 1.2 continued

Source	Jurisdiction	Effective Month	Month/Year Observed	Use Rate	Comments
Hearne (1981)	Ireland	2/79	Fall '78	19%	Drvs Nat'l rds
			Fall '78	9%	Drvs other roads
			Sum '79	46%	Drvs nat'l rds
			Sum '79	38%	Drvs nat'l rds
Hakkert & others (1981)	Israel	7/75	pre-law	6%	
			8/75	77%	
			1976	83%	
			1977	70%	
Fisher (1980)	Netherlands	6/75	1974	11%	Urban
			1974	24%	Rural
			7/76	58%	Urban
			7/76	75%	Rural
Vaaje (1986)	Netherlands	6/75	1983	46%	Urban
			1983	65%	Rural
Toomath (1977)	New Zeland	6/72	5/72	40%	
			6/72	87%	
			1974	83%	
			1975	89%	
Fisher (1980)	Norway	9/75	pre-law	15%	Urban
			pre-law	37%	Rural
			1976	28%	Urban
			1976	59%	Rural
			1977	30%	Urban
			1977	63%	Rural
Oranen & Koivurova (1980)	Norway	9/75	3/80	74%	Urban
			3/80	90%	Rural
Fisher (1980)	Puerto Rico	1/74	7/73	5%	
			5/74	24%	
			9/74	7%	
			1/76	34%	
			5/77	14%	
Fernie (1980)	South Africa	12/77	11/77	18%	
			3/78	62%	
			9/79	70%	
Bohlin (1979)	Sweden	1/75	1974	35%	
			1975	84%	
Tingvall in Fisher (1980)	Sweden	1/75	1974	36%	
			1978	79%	Urban
			1978	87%	Rural
Norin & others (1984)	Sweden	1/75	1983	80%	
Fisher (1980)	Switzerland	1/76	pre-law	35%	
			2/76	95%	Expressway drivers
			2/76	92%	Rural drivers
			2/76	89%	Urban drivers
			9/78	64%	Expressway drivers
			9/78	46%	Rural drivers
			9/78	33%	Urban drivers

Table 1.2 continued

Source	Jurisdiction	Effective Month	Month/Year Observed	Use Rate	Comments
Andreasson (1983)	Switzerland	7/81[2]	1982	77%	Expressways
			1982	76%	Rural
			1982	62%	Urban
Federal Inst. Streets in Fisher (1980)	W. Germany	1/76	8/75	28%	
			11/75	32%	
			1/76	50%	
			3/77	46%	
			9/77	48%	
			9/78	58%	
Marburger (1986)	West Germany	1/76	9/84	92%	Fines began
			3/86	94%	August 1985

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2. Switzerland's 1976 law declared invalid by the Supreme Court in 9/77 and reinstated by the Government on 7/1/81.

Table 1.3

EFFECTS OF NON-U.S. SEAT BELT LAWS ON FATALITIES

Investigators	Jurisdiction	Month Effective	Post-Law Months	Fatality Change	Significance Level
Foldvary & Lane (1974)	Australia-Victoria	1/71	9	-15%	≤0.05
Trinca & Dooley (1977)	Victoria	1/71	48	-37%	
Andreassend (1976)	Victoria	1/71	10	-15%	
Joubert (1979)	Victoria	1/71	12	-15%	
McDermott & Hough (1979)	Victoria	1/71	84		≤0.01
Trinca (1984)	Victoria	1/71	144	-60%	
Johinke (1977)	Queensland	1/72		-14%	
Bhattacharyya & Layton (1979)	Queensland	1/72		-46%	
Crinion (1975)	South Aust.	11/71	12	-8%	
Fisher (1980)	Australia			-20%	
Snow (1979)	Canada-Ontario	1/76	6	-13%	
Sheils (1978)	Saskatch.	7/77	12	-20%	
Jonah & Lawson (1984)	Brit. Col.	10/77	51	-30%	≤0.01
	Ontario	1/76	72	-26%	≤0.05
	Quebec	8/76	65	-17%	ns
	Saskatch.	7/77	52	-37%	≤0.10
				-35%	≤0.05[1]
Hedlund (1986)	Brit. Col.	10/77	60	-52%	
	Ontario	1/76	72	-12%	
	Quebec	8/76	65	-18%	
	Saskatch.	7/77	52	-29%	
Nordic Traffic Safety Council (1984)	Denmark	1/76	12	-1%	
Hedlund (1986)	Denmark	1/76	12	-13%	
Mackay (1984b)	England	2/83	11	-25%	
Pye & Waters (1984)	England	2/83	3	-80%	≤0.001
Durbin & Harvey (1985)	England	2/83	23	-18%[2]	
				-25%[3]	

Table 1.3 continued

Investigators	Jurisdiction	Month Effective	Post-Law Months	Fatality Change	Significance Level
Chodkiewicz & Dubarry (1977)	France	7/73	30	-21%	
Hartemann & others (1984)	France	7/73	114	-50%	
Hearne (1981)	Ireland	2/79	11	-0.7%	
Hakkert & others (1981)	Isreal	7/75	30	-42%[2] -44%[3]	
Hedlund (1986)	Isreal	7/75	30	-41%	
Toomath (1977)	New Zealand	6/72	24	+3%[4]	
Hedlund (1986)	New Zealand	6/72	24	-43%	
McCarthy & others (1984)	Norway	9/79		-21%	
Nordic Traffic Safety Council (1984)	Norway	9/79	12	-10%	
Hedlund (1986)	Norway	9/75	12	-29%	
McCarthy & others (1984)	South Africa	12/77		-8%	
McCarthy & others (1984)	Sweden	1/75		-14%	
Bohlin (1979)	Sweden	1/75	12	-12%	
Norin & others (1984)	Sweden	1/75	12	-12%	
Fisher (1980)	Switzerland	1/76	12	-12%	
Hedlund (1986)	Switzerland W. Germany	7/81[5] 1/76	12 6[6]	-15% -25%	

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1. Crash data for the period 7/1/77 to 12/31/82 were analyzed; actual fatality rates were significantly different from predicted rates only in 1980 ($p \leq 0.10$) and 1981 ($p \leq 0.05$)

2. Drivers only

3. Front-seat passengers

4. In contrast, nonoccupant fatalities increased almost 40% during this period

5. Switzerland's 1976 law declared invalid by the Supreme Court in 9/77 and reinstated by the Government in 7/1/81.

6. This study compared the pre- and post-fine period 1-6/84 to 1-6/85

Table 1.4
EFFECTS OF U.S. SEAT BELT LAWS ON FATALITIES

Investigators	Jurisdiction	Effective Date	Post-Law Months	Fatality Change	Significance Level
Lund & others (1986a)	NY	12/84	9	-9%	≤0.05
Hedlund (1986)	NY	12/84	9	-15%	
Latimer & Lave (1986)	NY	12/84	6	-20%	
Pace & others (1986)	NY	12/84	3		-27%
Wagenaar & others (1987b)	MI	7/85	12	-10%	ns
Mortimer (1986)	IL	7/85	9	-3%	
Lund & others (1986b)	NY	12/84	13	-5%	≤0.01
	NJ	3/85	10	-4%	ns
	MI	7/85	6	-4%	ns
	IL	7/85	6	-7%	ns
Campbell & others (1986)	NY	12/84	13	-8%	≤0.10
	NJ	3/85	10	-6%	≤0.10
	IL	7/86	6	-9%	ns
	MI	7/85	6	-16%	≤0.10
	TX	9/85	4	-18%	≤0.01
	NB	9/85	4	-11%	ns
	MO	9/85	3	+5%	ns
	NC	10/85	3	-0.4%	ns
	All			-10%	ns
Hoxie & Skinner (1987)	NY	12/84	19	-7%	ns
	NJ	3/85	16	-2%	ns
	IL	7/85	12	-1%	ns
	MI	7/85	12	-14%	≤0.10
	TX	9/85	10	-18%	≤0.01
	MO	9/85	9	+18%	≤0.01
	NC	10/85	9	-5%	ns
	All			-6%	ns
Partyka (1987)	All[1]	Variable[2]	Variable[2]	-7%	

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1. NY, NJ,IL, MI, TX, NB, MO, NC

2. Different for each state depending on date law enacted.

2 METHODS

2.1 Research Design

We evaluated eight U.S. states that implemented mandatory seat belt use laws prior to October, 1985 using monthly data on traffic fatalities from January 1976 through June 1986. We used a longitudinal or **time-series design** to ensure that observed changes in fatalities were not due to long-term cycles or trends, or were not a result of a regression to the mean effect. In the absence of random assignment, time-series research designs have the highest possible levels of internal validity (Cook and Campbell, 1979).

To further strengthen causal inferences concerning the relationship between compulsory seat belt laws and traffic fatalities, we examined **two types of control groups** one would not expect to be affected by the new laws. First, we paired each "experimental" state that recently implemented a seat belt law with a neighboring "control" state that did not implement a belt law during the period under study. States analyzed include: New York with a belt law versus Pennsylvania without, New Jersey versus Maryland, Michigan versus Ohio, Illinois versus Indiana, Texas versus Georgia, Nebraska versus Kansas, Missouri versus Tennessee, and North Carolina versus Virginia.[1] Second, within the experimental states we examined two categories of traffic fatalities not directly affected by the new laws--rear-seat occupants and nonoccupants (including pedestrians, motorcyclists, and pedalcyclists).

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1. Two of the comparison states, Ohio and Tennessee, implemented compulsory belt use laws in the spring of 1986. Analyses involving these states were limited to the period in which no belt law was in effect.

2.2 Data Collection

All fatality data were based on the Fatal Accident Reporting System maintained by the U.S. National Highway Traffic Safety Administration. Monthly counts of the number of fatalities were calculated separately within each state for front-seat occupants, rear-seat occupants, and nonoccupants. Occupant fatalities included only those traveling in passenger cars, vans, light trucks, and utility vehicles. Medium and heavy trucks, buses, and a variety of special vehicles were excluded because some are exempted from provisions of the seat belt laws and others were covered by pre-existing regulations requiring seat belt use. All analyses were limited to persons age 10 and over because compulsory restraint use laws for young children were implemented several years before the adult seat belt laws took effect. Although most child restraint laws are limited to those under age 4, spill-over effects on older children of those earlier laws have been reported (Wagenaar and Webster, 1986). The length of the resulting time series varied from 107 baseline months in New York to 117 baseline months in North Carolina, and from 9 post-law months in North Carolina to 19 post-law months in New York.

Exposure to risk of crash involvement was controlled by dividing all of the fatality frequency time-series by the number of vehicle miles traveled (VMT) within each of the states under study. The resulting rates of fatalities per VMT were used in all subsequent analyses. State-specific VMT figures by month were obtained from the U.S. Federal Highway Administration and are based on traffic counter and motor fuel sales data.

2.3 Statistical Methods

We used the time-series intervention analysis methods of Box and Jenkins (1976). On a conceptual level, the analytic strategy involves explaining as much of the variance in fatality rates on the basis of the past history of those rates, before attributing

any of the variance to an exogenous variable, such as implementation of a seat belt law. This approach of intervention analysis was particularly appropriate for the current study, because the objective was to identify significant shifts in fatality rates associated with seat belt laws, independent of observed regularities in the history of each series. Ordinary least squares regression and other commonly used statistical procedures were not appropriate for the present study because they assume independent observations. However, a series of observations over time, such as the fatality rate series analyzed here, are highly autocorrelated, violating the assumption of independence, and leading to biased standard error estimates using conventional methods.

Baseline Auto-regressive Integrated Moving Average (ARIMA) models were iteratively developed for each time series, repeatedly going through cycles of specifying a model, estimating it, and evaluating its adequacy in terms of accounting for all significant autocorrelation patterns in the series. All of the time series were natural-logarithm transformed prior to parameter estimation to reduce heteroscedasticity. All of the final models met the multiple criteria for model adequacy identified by Box and Jenkins (1976), including significant noise model parameters, low correlations among parameters, and insignificant residual autocorrelations.

Transfer functions were added to the noise models to test for effects of seat belt laws. Given the short post-law period for which data were available, simple shift transfer function models were used to represent potential effects of the belt laws. Additional transfer functions were added to the models for selected time series. The substantial decline in the fatality rate in 1982 in most of the states was controlled by including a simple shift transfer function. The 1982 decline was due to a variety of factors, including a major economic recession, campaigns to reduce alcohol-impaired driving, and changes in the age structure of the population (Hedlund and others, 1984). Our objective was not to fully elucidate the causal structure underlying those fatality reductions, but rather to statistically control for those reductions when estimating the effects of recent compulsory seat belt laws.

Because the models are intrinsically nonlinear, the Gauss-Marquardt backcasting algorithm implemented in the software package BMDP2T was used to estimate the parameters (Dixon and others, 1983). All parameter estimates in the logarithm metric were converted to an estimated percent change in the series after the seat belt law, from levels expected given baseline patterns, using: $(e^{\omega} - 1)100$. A plot of each time series analyzed, along with the final statistical model for each series, is shown in Appendix A. Major findings are briefly reviewed here.

3 RESULTS

Significant declines in the rate of front-seat occupant deaths per VMT occurred in three of the eight states with mandatory seat belt laws (Figure 3.1). The fatality rate declined 8.3% in Michigan, 12.4% in New York, and 15.5% in Texas. Intervention parameter estimates were in the expected direction (though not significant) in New Jersey and Illinois. The fatality rate increased in Missouri, Nebraska, and North Carolina, but only in Missouri was the estimated increase larger than two standard errors.[2] While these analyses control for long-term trends and cycles within each state, and control for changes in exposure via rates per VMT, these state-specific changes in fatalities may still simply reflect broader regional or national changes due to other factors. To ensure that observed fatality changes were associated with the seat belt laws and not other factors, we analyzed the rate of fatalities per VMT in a state with a new belt law **relative to** the rate of fatalities per VMT in a neighboring state without a belt law during the period studied. In other words, the fatality rate in the target state was divided by the rate in the comparison state.

Analyses of the relative rates again indicated significant declines in fatalities associated with seat belt laws in three of the eight states: New York, 7.1%; New Jersey, 24.5%; and Nebraska, 19.3% (Figure 3.2). However, as noted in the previous paragraph, two of these three, (New Jersey and Nebraska) showed no significant decrease when examining the state alone, without taking into account the experience in comparison states. In addition to significant reductions in the relative rates of fatalities in three states, time-series modeling produced estimates in the expected direction (although not significant) in an additional four states.

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2. Technically not statistically significant because we hypothesized a fatality reduction following implementation of belt laws, and consequently used one-tailed tests.

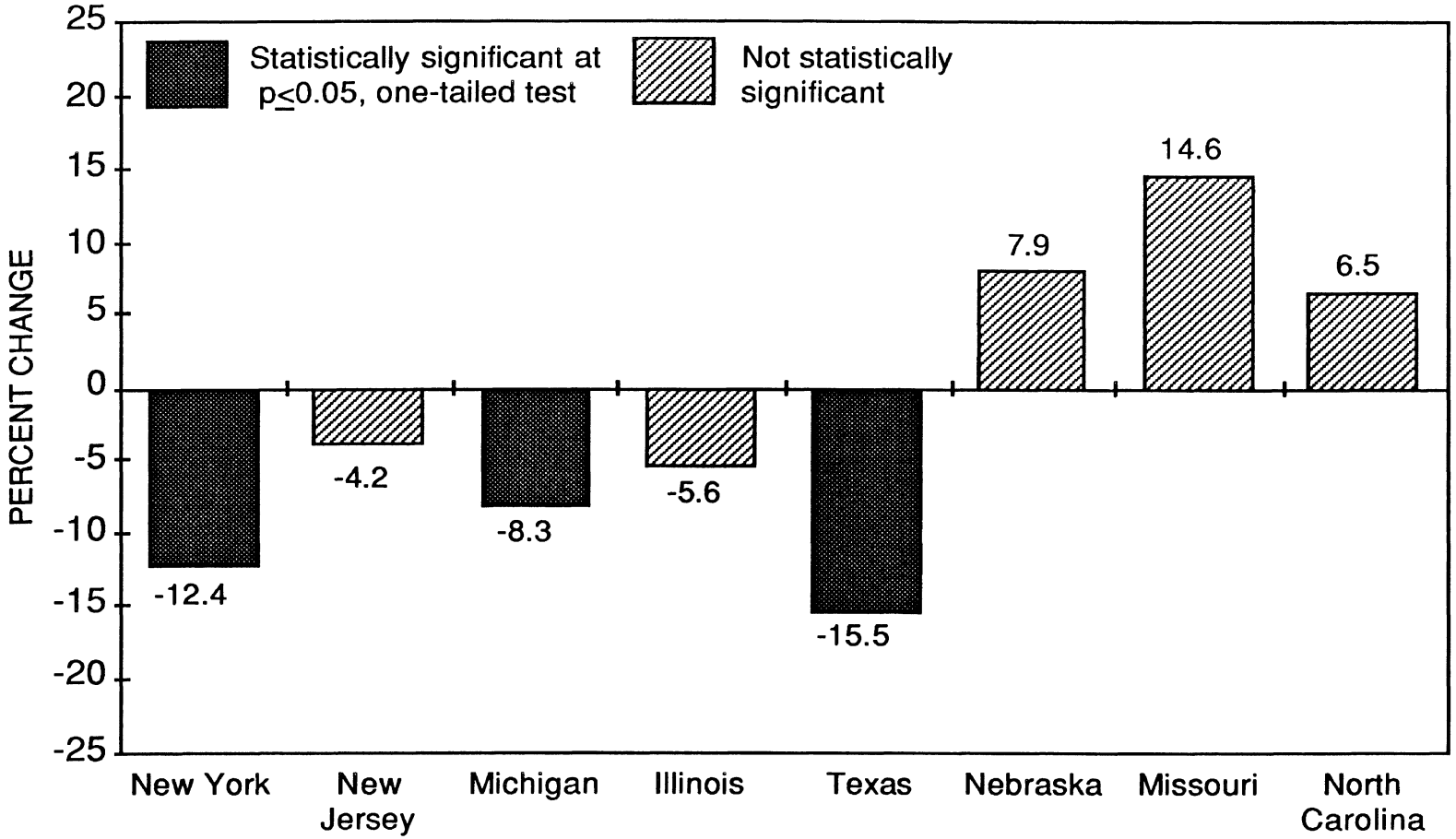

Figure 3.1: Percent Change in Rate of Fatalities per VMT Associated with Seat Belt Laws: Front-seat Occupants Age 10 and Over

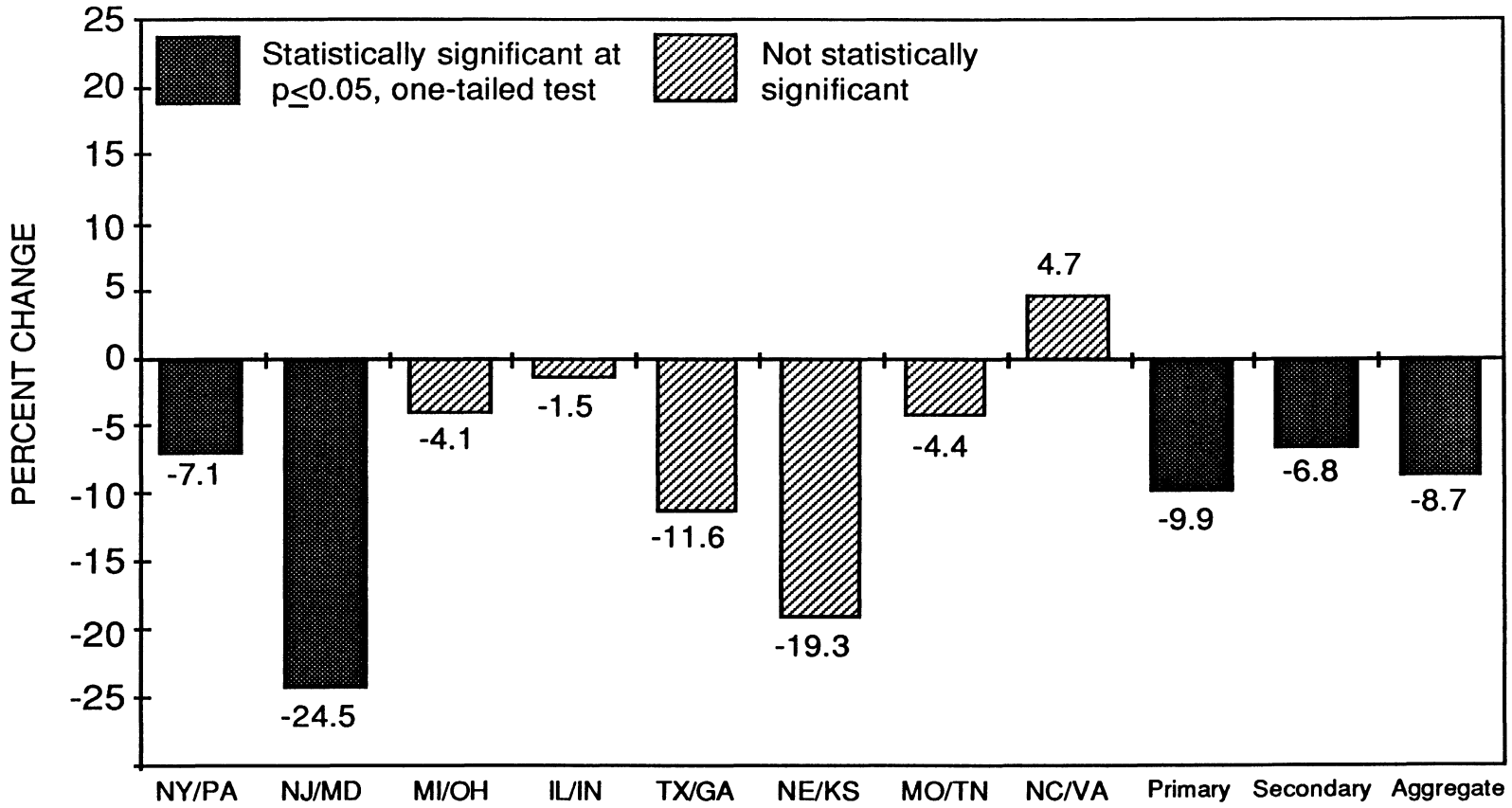

Figure 3.2: Percent Change in Rate of Fatalities per VMT Among Front-seat Occupants Age 10 and Over: Belt Law Relative to Comparison States.

Clearly the small number of post-law data points available (9 to 19 months), and the substantial baseline variability in fatality rates over time, results in moderately large standard errors and what appear to be inconsistent results across states. To reduce this background variation, we combined the eight belt-law states, and estimated the aggregate effect of the belt laws in these eight states. The state-specific time series were aligned on the month each state's belt law took effect and the number of fatalities and amount of vehicle mileage traveled were summed. The eight comparison states were similarly summed. The result was time series in which each month no longer represented a specific month in time, but rather represented the ordinal month from the point at which belt laws were implemented. Dividing the fatality rate per VMT for the belt-law states as a group by the fatality rate per VMT for the comparison states as a group resulted in an aggregate relative rate. Time-series modeling of the aggregate relative rate estimated a statistically significant 8.7% decline associated with belt laws in these states.

One obvious explanation for the differential effects of seat belt laws across states is the size of the change in belt use caused by the law. Most states experienced an increase in belt use from about 16% before to 45% a few months after laws took effect (Table 1.1). Texas had a larger than average increase in belt use (from 15 to 66%) and Illinois a smaller than average increase (from 16 to 30%). Given the different survey methods used in each state, and the standard errors of our estimates of belt law effects on fatalities, we are not in a position to argue that cross-state differences in our fatality reduction estimates reflect differences in belt use rates across states.

Nevertheless, specific provisions of the law, such as primary versus secondary enforcement,[3] and the intensity with which it is enforced are expected to influence belt use rates. To take into account these major differences in the laws across states, we conducted time-series analyses of two groups of states--states with primary enforcement

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3. Secondary enforcement means that police officers may only issue citations for failure to use belts if the motorist is first stopped for some other offense. That is, a motorist may not be stopped solely for failure to use seat belts.

versus states with secondary enforcement only. Because North Carolina and Missouri were not actively enforcing their laws during this period they were excluded from these analyses. Results indicated a significant 9.9% fatality reduction in the primary enforcement states, and a significant 6.7% fatality reduction in secondary enforcement states (Figure 3.2). As expected, states with primary enforcement experienced larger fatality reductions than states limited to secondary enforcement. However, it is worth noting that clear benefits also accrued from secondary enforcement belt laws, provided citations were actually issued to violators.

Finally, in addition to controlling for other plausible explanations for observed fatality declines by including comparison states, we conducted time-series analyses of rates of rear-seat occupant deaths and nonoccupant (motorcycle, pedalcycle, and pedestrian) deaths in the states with seat belt laws. All of the laws examined here are limited to front-seat occupants; as a result, rear-seat occupants along with nonoccupants serve as useful comparison groups. Analyses of aggregate fatality rates for the eight belt-law states revealed no change in fatality rates among either rear-seat occupants or nonoccupants. This result substantially increased our level of confidence in attributing observed declines in front-seat fatalities to the seat belt laws.

4 DISCUSSION

Our results confirm that laws requiring seat belt use can significantly reduce rates of motor vehicle fatalities. However, one cannot expect the fatality declines to be clearly demonstrable within single jurisdictions a short time after the laws are implemented. The nature of fatality trends over time, and the amount of unpredictable variation in number of deaths from month to month, means that a minimum of a 6 to 10% reduction over a 6 to 12 month period is required before the reduction can be reliably identified. Despite the lack of statistical significance for the estimated effects of seat belt laws in some jurisdictions, it is premature to conclude that laws in those states had **no** effect. As additional data become available, increasing the statistical power of analytic techniques used, some of the state-specific estimates obtained in the current study may become statistically significant. Results from our most powerful analyses, those involving aggregate effects across several states, clearly demonstrate significant fatality reductions. Moreover, use of comparison states and comparison groups not directly affected by the seat belt laws increases our confidence in interpreting the observed declines as caused by the mandatory seat belt use laws.

In terms of the magnitude of the effects of compulsory belt use laws, one can expect a U.S. law that permits primary enforcement and is actually enforced at moderate levels to result in about a 10% reduction in traffic fatalities. A law that permits secondary enforcement only or is enforced at very low levels will have less effect. Although some advocates of compulsory seat belt use have indicated that substantially larger declines in traffic fatalities would result, a 10% decline in a leading cause of death for the entire population represents a resounding public policy success. How many major programs aimed at reducing disease and injury can document an immediate 10% decline in mortality due to that cause of death across an entire population of millions of people? Moreover, effective implementation of a compulsory seat belt use policy

requires minimal expenditure of resources when compared to efforts to reduce mortality attributable to other leading causes of death (e.g., cardiovascular disease, cancer).

Despite the clear success of compulsory seat belt laws to date, much more remains to be done. As noted earlier, belt use in the U.S. typically peaks within a month or two of implementation of belt laws, partially decaying after that point. Special enforcement efforts not only can arrest that decline, but further increase belt use rates, at least temporarily (Williams and others, in press). Clearly, our results demonstrate that belt laws with primary rather than secondary enforcement provisions are needed. We believe that rigorous enforcement of a primary seat belt law in the U.S. can achieve and maintain belt use rates of approximately 60%, in contrast to less than 20% under the most favorable conditions without compulsory use (i.e., extensive education and public information programs).

Even if asymptotic belt use of 60% were achieved throughout the U.S., declines in traffic fatalities of more than 20% are extremely unlikely. This is because of the differential between belt users and nonusers; that is, those at highest risk of involvement in serious traffic crashes are least likely to use belts (Evans and Wasielewski, 1983). Therefore, other avenues of reducing traffic crash-induced injury and death that do not require action on the part of each individual driver (such as airbags) must be pursued simultaneously with efforts to implement and enforce mandatory belt use laws.

5 REFERENCES

Andreassend, D.C. "Victoria and the Seat Belt Law, 1971." *Human Factors*, 18(6):593-600, 1976.

Andreasson, R. "Switzerland Shows What a Seat-belt Law Can Mean." *Journal of Traffic Medicine*, 11(2):25-26, 1983.

Arora, H.R. *Seat Belt Use by Canadian Drivers, November 1981*. Ottawa, Canada: Road Safety Directorate, Transport Canada, 1982.

Arora, H.R. *Seat Belt Use by Canadian Drivers, November 1983*. Ottawa, Canada: Road Safety Directorate, Transport Canada, 1985.

Ashton, S.J., G.M. Mackay, S. Camm. Seat Belt Use in Britain Under Voluntary and Mandatory Conditions. In *27th Annual Proceedings of the American Association for Automotive Medicine*, San Antonio, Texas. Morton Grove, IL: American Association for Automotive Medicine, 1983.

B.C. Research. *Restraint Usage in British Columbia During 80% Clicks, June 3 and 4, 1983: Executive Summary*. Vancouver, British Columbia: Insurance Corporation of British Columbia, 1983.

Bergen, A.T., L.G. Watson, D.E. Rivett, A.C. Shiels. "The Effect on Injury and Fatality Rates Due to Seat Belt Usage in Saskatchewan." In *23rd Annual Proceedings of the American Association for Automotive Medicine*, (pp. 412-425). Morton Grove, IL: American Association for Automotive Medicine, 1979.

Bhattacharyya, M.N., A.P. Layton. "Effects of Seat Belt Legislation on the Queensland Road Toll--An Australian Case Study in Intervention Analysis." *Journal of American Statistical Association*, 74(367):596-603, 1979.

Bohlin, N.I. "Twenty Years of Safety Belt Experience and the Effect of Safety Belt Legislation in Sweden." In *'79 International Symposium on Seat Belts in Tokyo*, (pp. 116-125). Tokyo, Japan: Japanese Council of Traffic Science, 1979.

Box, G.E.P., G.M. Jenkins. *Time Series Analysis: Forecasting and Control*. Revised edition. San Francisco, CA: Holden-Day, 1976.

Bunch, N.G., N.J. Hatfield, W.M. Hinshaw, K.N. Womack. *Observed Front Seat Occupant Restraint Use in Fourteen Texas Cities Before and After Safety Belt Use Legislation*. College Station, TX: Texas Transportation Institute, Texas A&M University System, 1986.

Burris, J.F. "The Swiss Seat Belt Law: Lessons for the United States." *Maryland State Medical Journal*, 35(9):759-751, 1986.

Campbell, B.J., J.R. Stewart, F.A. Campbell. *Early Results of Seat Belt Legislation in the United States of America*. Chapel Hill, N.C.: The University of North Carolina Highway Safety Research Center, 1986.

Chodkiewicz, J.P., D. Dubarry. "Effects of Mandatory Seat Belt Legislation in France." In *Proceedings of the Sixth International Conference of the International Association for Accident and Traffic Medicine*, (pp. 40-44). Melbourne, Australia: January 31-February 4. 1977.

Cook, T.D., D.T. Campbell. *Quasi-experimentation: Design and Analysis Issues for Field Settings*. Chicago, IL: Rand McNally, 1979.

Crinon, J.D., L.A. Foldvary, J.C. Lane. "The Effect on Casualties of a Compulsory Seat Belt Wearing Law in South Australia." *Accident Analysis and Prevention*, 7(2):81-89, 1975.

DataCom Opinion Research Corp. *Manitoba Shoulder Belt Observation Survey, June, 1984: Summary of Results*. Winnepeg, Manitoba: Manitoba Traffic Safety Committee, 1984.

Department of Transport. *Compulsory Seat Belt Wearing Report by the Department of Transport*. London, England: Her Majesty's Stationery Office, 1985.

Dixon, W.J., M.B. Brown, L. Engelman, et al. *BMDP Statistical Software: 1983 Printing with Additions*. Berkeley, CA: University of California Press, 1983.

Durbin, J., A.C. Harvey. "The Effects of Seat Belt Legislation on Road Casualties in Great Britain: Report on Assessment of the Statistical Evidence." *Compulsory Seat Belt Wearing Report by the Department of Transport*, Annex, (pp. 1-A46). London, England: Her Majesty's Stationery Office, 1985.

Evans, L., P. Wasielewski. "Risky Driving Related to Driver and Vehicle Characteristics." *Accident Analysis and Prevention*, 15(2):121-136, April 1983.

Fernie, B.E. *Compulsory Wearing of Seat Belts in South Africa: Interim Evaluation of Effectiveness*. Pretoria, South Africa: National Institute for Transport and Road Research, 1980.

Fisher, F.G. *Effectiveness of Safety Belt Usage Laws*. [PB80 209901]. Washington, D.C.: U.S. Department of Transportation, National Highway Traffic Safety Administration, 1980.

Foldvary, L.A., J.C. Lane. "The Effectiveness of Compulsory Wearing of Seat-Belts in Casualty Reduction." *Accident Analysis and Prevention*, 6(1):59-81, 1974

Gerondeau, C. "Enaction of Seat Belt Use Laws in France." In *'79 International Symposium on Seat Belts in Tokyo*, (pp. 189-193). Tokyo, Japan: Japanese Council on Traffic Science, 1979.

Gerondeau, C. Mandatory Seat Belt Usage: The French Experience 1973/1981. In *International Symposium on Occupant Restraints*. (32 p.). Toronto, Ontario, Canada: June 1-3, 1981.

Hakkert, A.S., D.M. Zaidel, E. Sarelle. "Patterns of Safety Belt Usage Following Introduction of a Safety Belt Wearing Law." *Accident Analysis and Prevention*, 13(2):65-82, 1981.

Hartemann, F., C. Henry, G. Faverjon, C. Tarriere, C. Got, A. Patel. "Ten Years of Safety Due to the Three-Point Seat Belt." *Advances in Restraint Systems: Design, Performance and Usage*, (pp.7-13). Warrendale, PA: Society for Automotive Engineers, Inc., 1984.

Hatfield, N.J., W.M. Hinshaw, N.G. Bunch, R. Bremmer. *Observed Pre-Law Safety Belt Use by Adult Front Seat Occupants in Twelve Texas Cities*. College Station, TX: Texas Transportation Institute, Texas A&M University System, 1985.

Hearne, R. *The Initial Impact of the Safety Belt Legislation in Ireland*. Dublin, Ireland: An Foras Forbartha, The National Institute for Physical Planning and Construction Research, 1981.

Hedlund J., R. Arnold, E. Cerrelli, S. Partyka, P. Hoxie. "An Assessment of the 1982 Traffic Fatality Decrease." *Accident Analysis and Prevention*, 16(4):247-261, 1984.

Hedlund, J. "Casualty Reductions: Results From Safety Belt Use Laws." *Effectiveness of Safety Belt Use Laws: A Multinational Examination*, [DOT HS 807018], (pp. 73-97). Washington, D.C.: National Highway Traffic Safety Administration, 1986.

Hoxie, P., B. Skinner. "Fatality Reductions from Mandatory Seatbelt Usage Laws." *Restraint Technologies: Front Seat Occupant Protection*, (pp.199-203). Warrendale, PA: Society of Automotive Engineers, Inc., 1987.

Insurance Institute for Highway Safety. "North Carolina Leads Nation in Seat Belt Use." *Status Report*, 22(3):5, 1987a.

Insurance Institute for Highway Safety. "Seat Belt Use Rates Continue to Vary Among the States." *Status Report*, 22:(3):6, 1987b.

Johinke, A.K. "South Australian Experience with the Compulsory Wearing of Seat Belts." In *Proceedings of the Sixth International Conference of the International Association for Accident and Traffic Medicine*, (pp. 125-129). Melbourne, Australia: January 31-February 4, 1977.

Jonah, B.A., J.J. Lawson. "The Effectiveness of Canadian Mandatory Seat Belt Laws." *Accident Analysis and Prevention*, 16(5/6):433-450, 1984.

Jonah, B.A., J.J. Lawson. "Safety Belt Use Rates and User Characteristics." *Effectiveness of Safety Belt Use Laws: A Multinational Examination*, [DOT HS 807018], (pp. 43-72). Washington, D.C.: National Highway Traffic Safety Administration, 1986.

Joubert, P.N. "Development and Effects of Seat Belt Laws in Australia." In '79 *International Symposium on Seat Belts in Tokyo*, (pp. 126-131). Tokyo, Japan: Japanese Council of Traffic Science, 1979.

Lassarre, S. "The Introduction of the Variables 'Traffic Volume,' 'Speed' and 'Belt-wearing' into a Predictive Model for the Severity of Accidents." *Accident Analysis & Prevention*, 18(2):129-134, 1986.

Latimer,E.A., L.B. Lave. "Initial Effects of the New York State Auto Safety Belt Law." *American Journal of Public Health*, 77(2):183-186, 1987.

Lund, A.K., J. Pollner, A.F. Williams. *Preliminary Effects of Mandatory Seat Belt Use Laws: Science versus Politics.* Washington, D.C.: Insurance Institute for Highway Safety, 1986a.

Lund, A.K., P. Zador, J. Pollner. *Motor Vehicle Occupant Fatalities in Four States with Seat Belt Use Laws.* Washington, D.C.: Insurance Institute for Highway Safety, 1986b.

Mackay, M. "Legislation for Seat Belt Use in Britain." *Advances in Belt Restraint Systems: Design, Performance, and Usage*, (pp. 153-160). Warrendale, PA: Society for Automotive Engineers, Inc., 1984a.

Mackay, M. Seat Belt Use Under Voluntary and Mandatory Conditions and its Effect on Casualties. In *Symposium on Human Behavior and Traffic Safety*, (pp. 259-283). Warren, MI: General Motors Research Laboratories, September 23-25, 1984b.

Manders, S.L. *Restraint Use in Victoria: Results of March 1984 Survey.* Melbourne, Australia: Road Traffic Authority, 1984.

Marburger, E.A. "Safety Belt Use Rates." In *Effectiveness of Safety Belt Use Laws: A Multinational Examination.* [DOT HS 807018], (pp. 25-41). Washington, D.C.: National Highway Traffic Safety Administration, 1986.

Matthews, M.L. "Seat Belt Usage in Ontario Four Years After Mandatory Legislation." *Accident Analysis and Prevention*, 14(6):431-438, 1982.

McCarthy, R.L., R.K. Taylor, S.B. Sanford, R.C. Lange. "Seat Belts: Effectiveness of Mandatory Use Requirements." *Advances in Belt Restraint Systems: Design, Performance and Usage.*, (pp.161-171). Warrendale, PA: Society for Automotive Engineers, Inc., 1984.

McDermott, F.T., D.F. Hough. "Reduction in Road Fatalities and Injuries after Legislation for Compulsory Wearing of Seat Belts: Experience in Victoria and the Rest of Australia." *British Journal of Surgery*, 66:518-521, 1979.

Mortimer, R.G. *Seat Belt Use by Front Seat Occupants in Illinois.* Champaign, IL: University of Illinois at Urbana-Champaign, Department of Health and Safety Studies, 1986.

Murray, E. *Results of Seat Belt Survey, July, 1984.* [Research Report 27]. St. Johns, Newfoundland: Highway Planning and Research, Department of Transportation, 1984.

New Brunswick Department of Transportation. *Results of Seat Belt Survey, August, 1984.* Fredericton, New Brunswick: Motor Vehicle Administration and Public Safety Coordination, 1984.

Nordic Traffic Safety Council. 37A *Restraints for Adults and Children in the Back Seats of Private Cars.* [Report 37A]. Appendix II and III. Oslo, Norway: Nordic Traffic Safety Council, 1984.

Norin, H., G. Carlsson, J. Korner. "Seat Belt Usage in Sweden and its Injury Reducing Effect." In *Advances in Belt Restraint Systems: Design, Performance, and Usage*, (pp 15-28). Warrendale, PA: Society of Automotive Engineers, Inc., 1984.

Oranen, L. *Use of Safety Belts: Investigation into Effect of Compulsory Use of Safety Belts on Volume of Use.* Helsinki, Finland: Central Organization for Traffic Safety, Research Department, 1977.

Oranen, L., M. Koivurova. *Seat Belt Use and Condition and Driver Attitudes.* Helsinki, Finland: Central Organization for Traffic Safety, 1981.

Pace, B.J., R. Thailer, T.G. Kwiatkowski. "New York State Mandatory Seatbelt Use Law: Patterns of Seatbelt Use Before and After Legislation." *The Journal of Trauma*, 26(11):1031-1033, 1986.

Partyka, S. "Mandatory Belt Use Law Effects in 1985." *Research Notes.* Washington D.C.: U.S. Department of Transportation, National Highway Traffic Safety Administration, National Center for Statistics and Analysis, February 1-4, 1987.

Pierce, J.A. "Safety Benefits of the Seat Belt Legislation and Speed Limit Reduction in Ontario." In *Proceedings of the 23rd Annual Conference of the American Association for Automotive Medicine*, (pp. 242-253). Morton Grove, IL: American Association for Automotive Medicine, 1979.

Pye, G., E.A. Waters. "Effect of Seat Belt Legislation on Injuries and Road Traffic Accidents in Nottingham." *British Journal of Medicine*, 288(6419):756-757, 1984.

Road Traffic Board of South Australia. *Seat Belt Usage Before and After a Multi-Media Advertising Campaign, August-November, 1982.* Walkerville, South Australia: 1983.

Robertson, L. "The Seat Belt Use Law in Ontario: Effects on Actual Use." *Canadian Journal of Public Health*, 69:154-157, 1978.

Rockerbie, R.A. Personal communication, February 16, 1983.

Rood, D. H., P.P. Kraichy, J. Carubia. *Evaluation of New York State's Mandatory Occupant Restraint Law: Volume I, Observational Surveys of Safety Restraint Use in*

New York State. [DOT HS 806950]. Albany, NY: SUNY-Albany, Institute for Traffic Safety Management and Research, 1985.

Schnerring, F. *Surveys of Seat Belt Wearing in New South Wales: 1970-1981.* New South Wales: Traffic Accident Research Unit, Traffic Authority of New South Wales, 1983.

Seeney, K.M. "Queensland Experience of Compulsory Wearing of Seat Belts." In *Proceedings of the Sixth International Conference of the International Association for Accident and Traffic Medicine*, (pp. 115-124). Melbourne, Australia: January 31-February 4, 1977.

Seidenstecher, K. Laws on Mandatory Seat Belt Use in Germany and Short Evaluation of the International Literature on Seat Belts. In *'79 International Symposium on Seat Belts in Tokyo* (pp. 194-202). Tokyo, Japan: Japanese Council of Traffic Science, 1979.

Shapiro, R.G., A.F. Williams, D.F. Preusser, A.K. Lund. *New York's Belt Use Regulation for Learner's Permit Holders.* Norwalk, CT: Dunlap and Associates East, Inc. and Washington, D.C.: Insurance Institute for Highway Safety, 1984.

Shiels, A.C. The Effects of Seat Belt Legislation: The Saskatchewan Experience. In *The 10th Annual Safety Conference of the Canada Safety Council.* Winnipeg, Canada: October 16-19, 1978.

Simpson, H.M., R.A. Warren. "Seat Belts and Traffic Safety: The Canadian Experience." R.N. Green and E. Petrucelli (eds.), *The Human Collison: Proceedings of the International Symposium on Occupant Restraints*, (pp. 73-83). Morton Grove, IL: American Association for Automotive Medicine, 1981.

Snow, J.W. "Seat Belt Legislation in Ontario, Canada: Its History and Effects." In *'79 International Symposium on Seat Belts in Tokyo*, (pp. 199-202). Tokyo, Japan: Japanese Council on Traffic Science, 1979.

Stepanec, M. Seat Belt Push Losing Pull? *Detroit Free Press*, March 9, 1987.

Stulginskas, J.V., I.B. Pless. "Effects of a Seat Belt Law on Child Restraint Use." *American Journal of Disabled Children*, 137:582-585, 1983.

Toomath, J.B. "Compulsory Seat Belt Legislation in New Zealand." In *Proceedings of the 6th International Conference of the International Association for Accident and Traffic Medicine*, (pp. 21-39). Melbourne, Australia: January 31-February 4, 1977.

Trinca, G.W., B.J. Dooley. "The Effects of Seat Belt Legislation on Road Traffic Injuries." *Australia and New Zealand Journal of Surgery*, 47(2):150-155, 1977.

Trinca, G.W. Thirteen Years of Seat Belt Use - How Great the Benefits. *Advances in Belt Restraint Systems: Design, Performance and Usage*, (pp. 1-5). Warrendale, PA: Society of Automotive Engineers, 1984.

Vaaje, T. "Safety Belt Usage Laws in Various Countries." *Effectiveness of Safety Belt Use Laws: A Multinational Examination.* [DOT HS 807018], (pp. 13-23). Washington, D.C.: National Highway Traffic Safety Administration, 1986.

Vulcan, A.P. "Victorian Experience with the Compulsory Wearing of Seat Belts." In *Proceedings of the Sixth International Conference of the International Association for Accident and Traffic Medicine*, (pp. 99-114). Melbourne, Australia: January 31-February 4, 1977.

Wagenaar, A.C., L.J. Molnar, K.L. Businski. *Direct Observation of Seat Belt Use in Michigan: December 1986.* Ann Arbor, MI: The University of Michigan Transportation Research Institute, 1987a.

Wagenaar, A.C., R.G. Maybee, K.P. Sullivan. *Michigan's Compulsory Restraint Use Policies: Effects on Injuries and Deaths.* Ann Arbor, MI: The University of Michigan Transportation Research Institute, 1987b.

Wagenaar, A.C., D. Webster, R.G. Maybee. "Effects of Child Restraint Laws on Traffic Fatalities in Eleven States." *Journal of Trauma*, in press.

Wagenaar, A.C., D. Webster. "Preventing Injuries to Children Through Compulsory Automobile Safety Seat Use." *Pediatrics*, 78(4):662-672, 1986.

Williams, A.F., A.K. Lund. "Seat Belt Use Laws and Occupant Crash Protection in the United States." *American Journal of Public Health*, 76(12):1438-1442, 1986.

Williams, A.F., J.K. Wells, A.K. Lund. *Shoulder Belt Use in Four States With Belt Use Laws*. Washington, D.C.: Insurance Institute for Highway Safety, 1986.

Williams, A.F., D.F. Preusser, R.D. Blumberg, A.K. Lund. "Results of a Seat Belt Use Law Enforcement and Publicity Campaign in Elmira, New York." *Accident Analysis and Prevention*, in press.

Appendix A

Time-series Models

Combination autoregressive integrated moving average/transfer function models used to assess the statistical significance and magnitude of hypothesized effects of seat belt laws were of the general form: $(1 - \phi_1 B - ...\phi_p B^p)\ (1 - \Phi, B - ...\Phi_P B^{Ps})\ (1 - B)^d(1 - B^s)^D\ \mathrm{Ln}Y_t = \alpha + (1 - \theta_1 B - ...\theta_q B^q)\ (1 - \Theta_1 B^s - ...\Theta_Q B^{Qs})u_t + \psi X_t + \omega I_t$, where B is the backshift operator such that $B(z_t)$ equals z_{t-1}, ϕ_1 to ϕ_p are the regular autoregressive parameters, Φ_1 to Φ_p are seasonal autoregressive parameters, d is the order of nonseasonal differencing, D is the order of seasonal differencing, s is the seasonal span, $\mathrm{Ln}Y_t$ is the natural logarithm transformation of the dependent time series, α is a constant, q is the order of the moving average process, θ_1 to θ_q are regular moving average parameters, Θ_1 to Θ_Q are seasonal moving average parameters, and u_t is a random error component. The two intervention components added to the autoregressive integrated moving average model are ψX_t and ωI_t, where ψ and ω are parameters to be estimated. X_t is a step function with the value 1 beginning at month t and 0 otherwise. I_t is a step function with the value 1 beginning at month t and 0 otherwise.

A plot of each major variable and the final statistical model are included here. Standard errors are shown in parentheses below each parameter estimate.

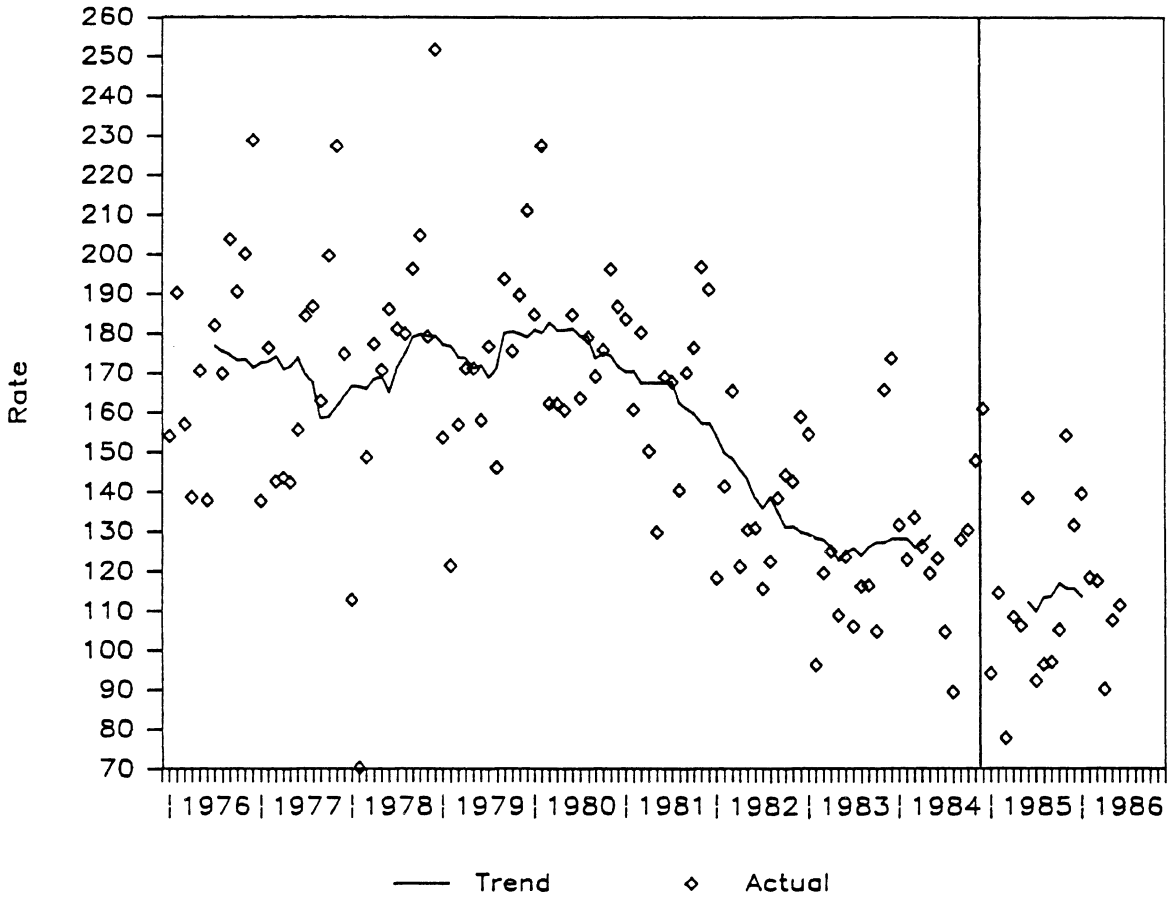

Figure A.1: Rate of New York State Front-seat Fatalities Age 10 and Over per 10 Billion VMT

Final Model

$$(1-B^{12})\,LnY_t = \underset{(.028)}{(1-.876B^{12})u_t} - \underset{(.032)}{(1-B^{12}).283X_{73}} - \underset{(.041)}{(1-B^{12}).133I_{108}}$$

Adjusted $R^2 = .59$

Effect of New York seat belt law, December 1984-June 1986: -12.4%*

* $p<0.05$, one-tailed test.

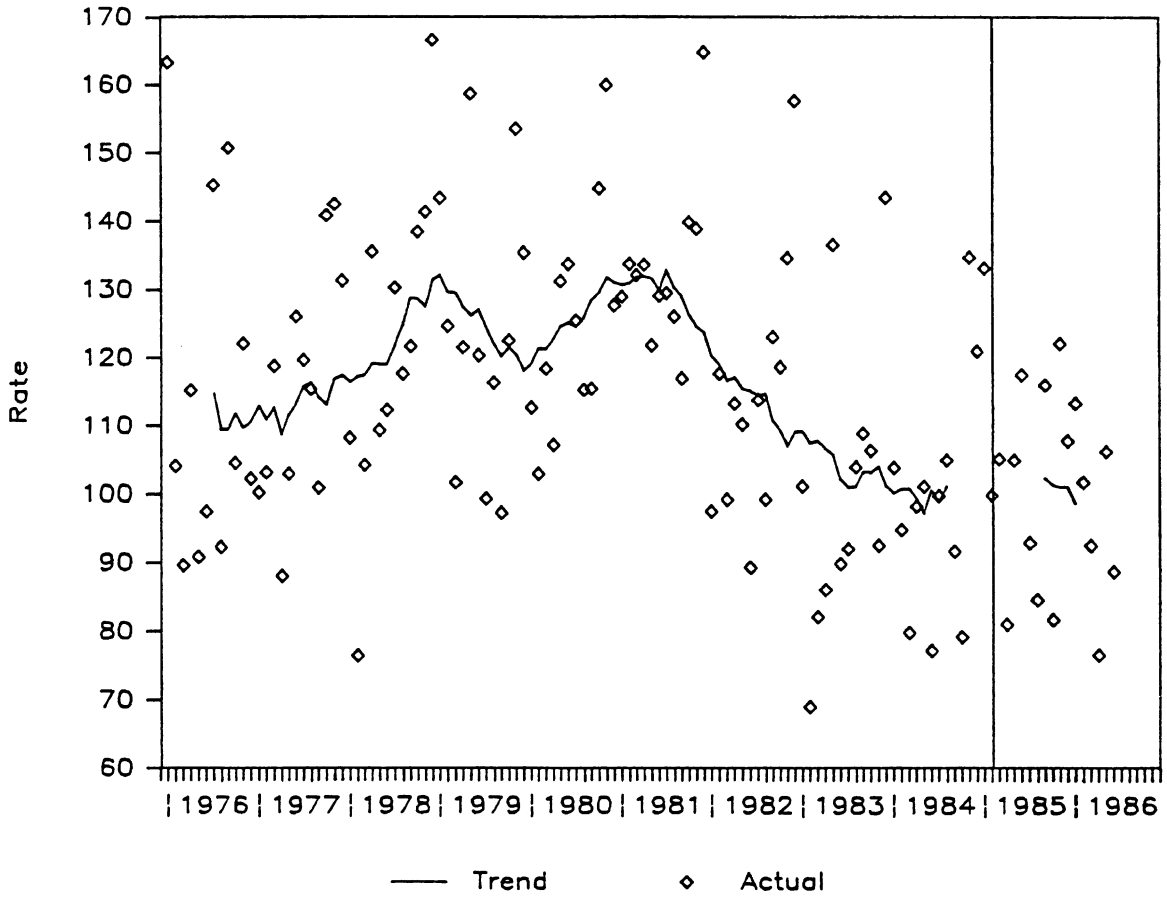

Figure A.2: Rate of New Jersey Front-seat Fatalities Age 10 and Over per 10 Billion VMT

Final Model

$$(1\text{-}B^{12})\, Ln Y_t = (1\text{-}\underset{(.028)}{.892}B^{12})u_t - (1\text{-}B^{12})\underset{(.029)}{.155}X_{73} - (1\text{-}B^{12})\underset{(.039)}{.043}I_{111}$$

Adjusted $R^2 = .39$

Effect of New Jersey seat belt law, March 1985-June 1986: -4.2%

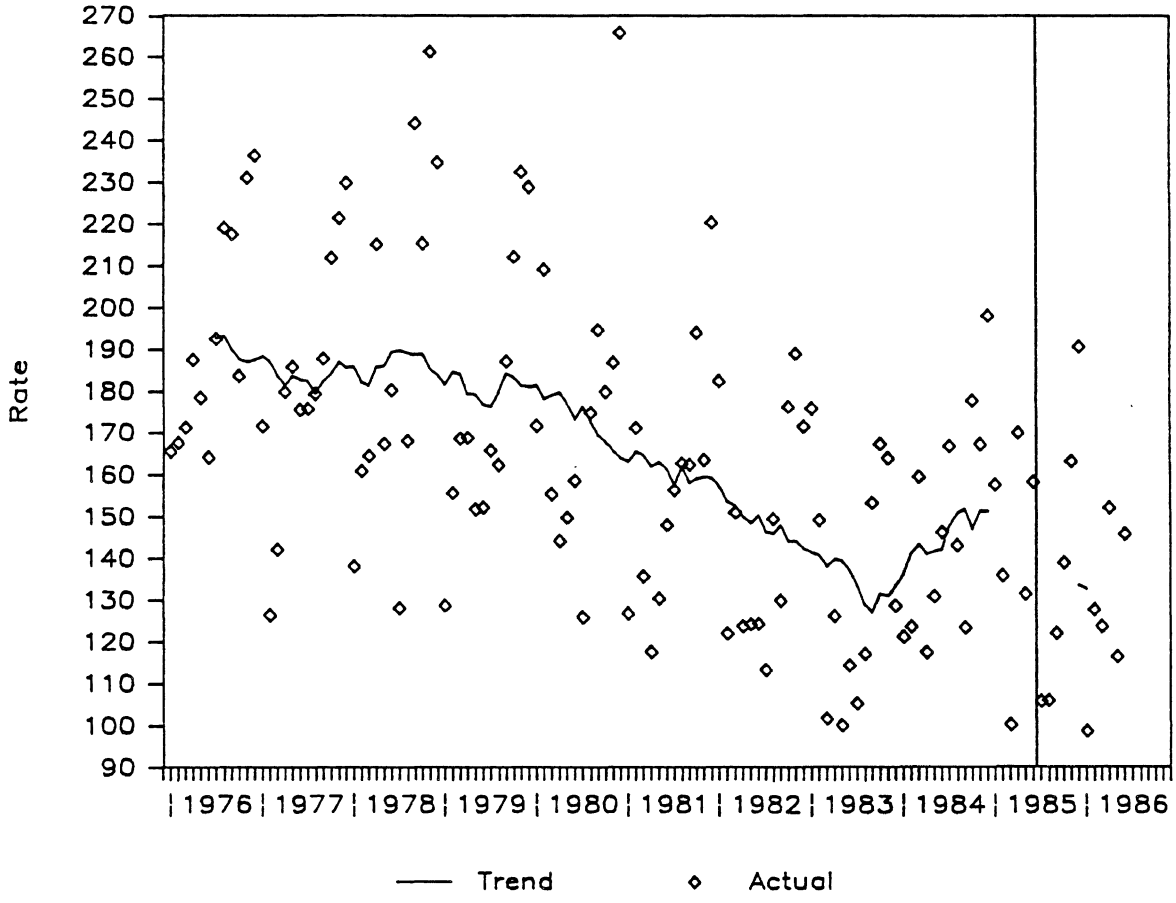

Figure A.3: Rate of Michigan Front-seat Fatalities Age 10 and Over per 10 Billion VMT

Final Model

$$(1-B^{12})\, Ln Y_t = \underset{(.031)}{(1-.884B^{12})u_t} - \underset{(.030)}{(1-B^{12})\,.213X_{73}} - \underset{(.043)}{(1-B^{12})\,.086I_{115}}$$

Adjusted $R^2 = .54$

Effect of Michigan seat belt law, July 1985-June 1986: -8.3%*

* $p<0.05$, one-tailed test.

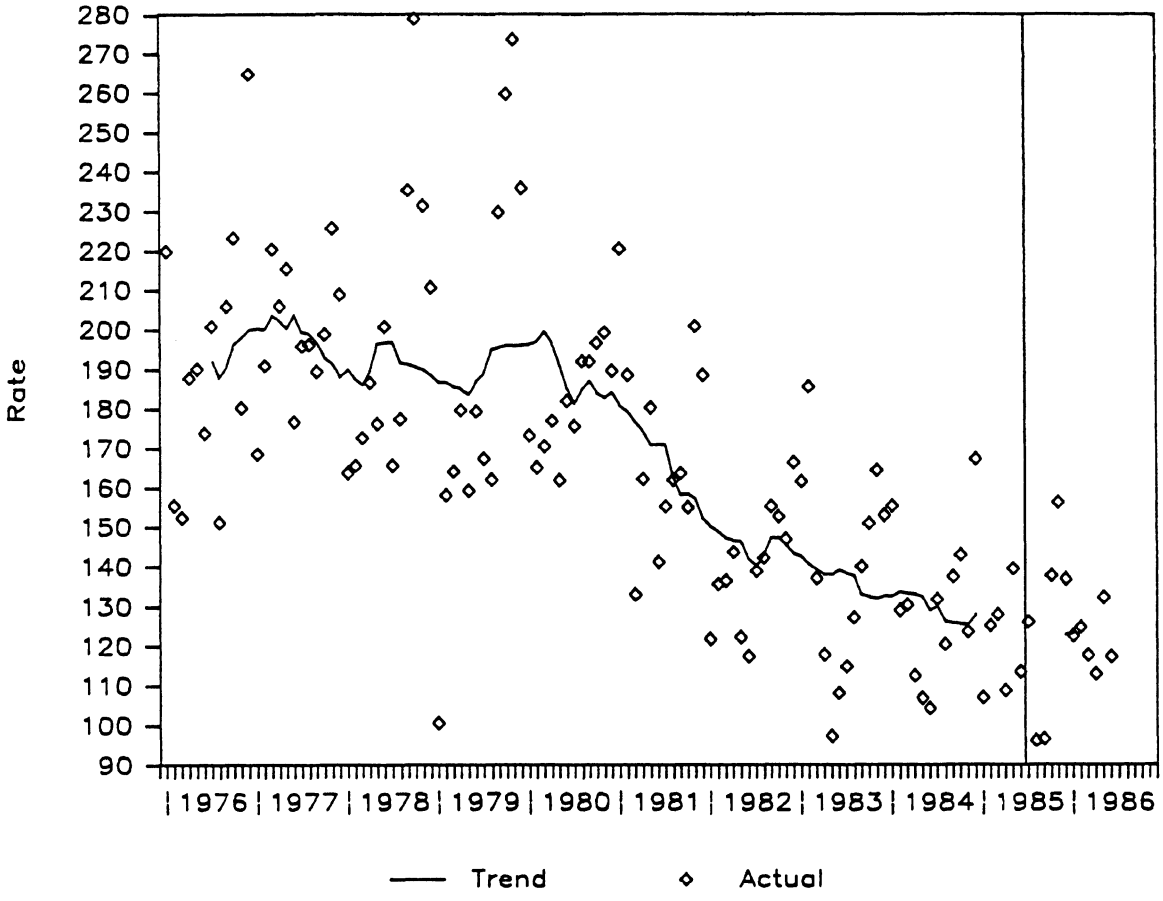

Figure A.4: Rate of Illinois Front-seat Fatalities Age 10 and Over per 10 Billion VMT

Final Model

$$(1-B^{12})(1+\underset{(.081)}{.408}B^{12})\ (1-\underset{(.082)}{.207}B)\ LnY_t = u_t - (1-B^{12})\underset{(.051)}{.239}X_{73} - (1-B^{12})\underset{(.057)}{.057}I_{115}$$

Adjusted $R^2 = .55$

Effect of Illinois seat belt law, July 1985-June 1986: -5.6%

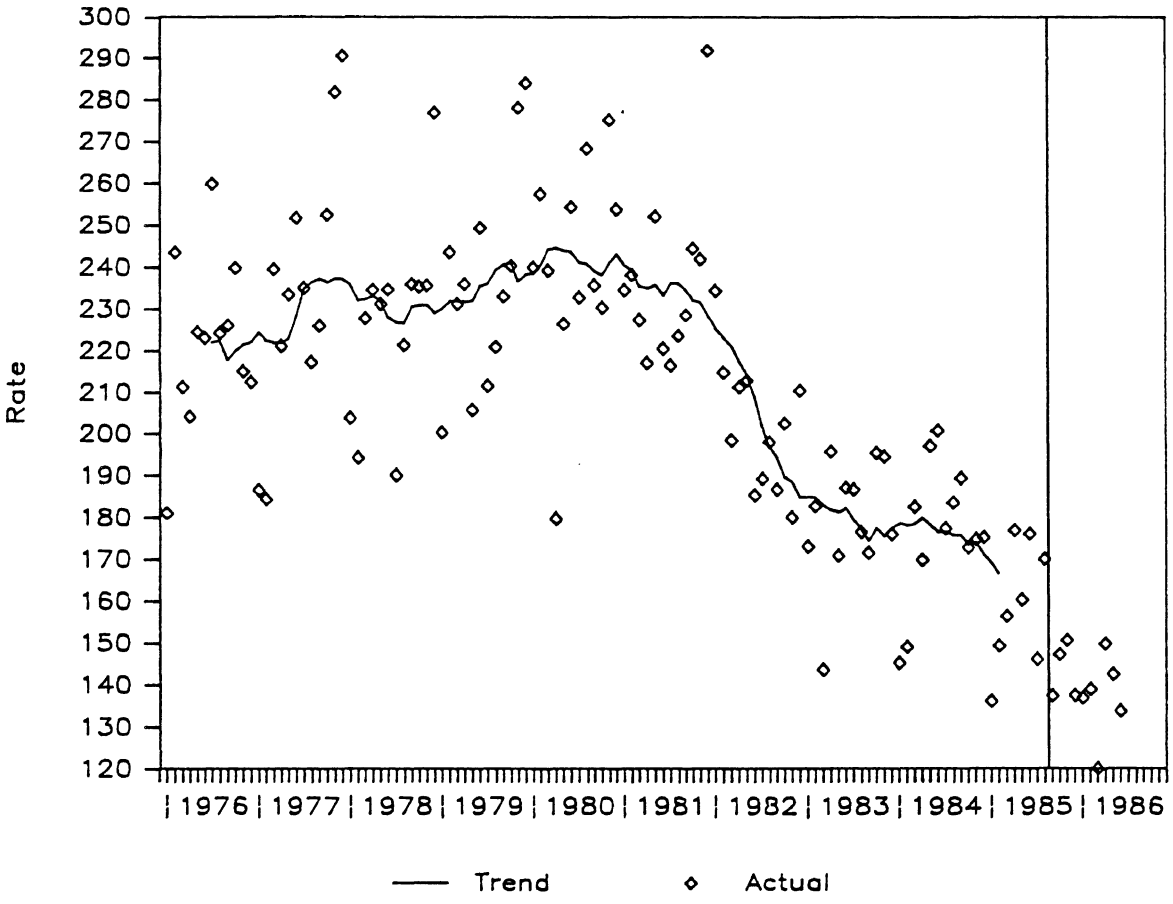

Figure A.5: Rate of Texas Front-seat Fatalities Age 10 and Over per 10 Billion VMT

Final Model

$$(1\text{-}B)(1\text{-}B^{12})\, Ln Y_t = \underset{(.028)}{(1\text{-}.877B^{12})}\ \underset{(.053)}{(1\text{-}.800B)u_t} - \underset{(.058)}{(1\text{-}B)(1\text{-}B^{12})\ .088X_{73}} - \underset{(.053)}{(1\text{-}B)(1\text{-}B^{12})\ .168I_{117}}$$

Adjusted $R^2 = .76$

Effect of Texas seat belt law, September 1985-June 1986: -15.5%*

* $p<0.05$, one-tailed test.

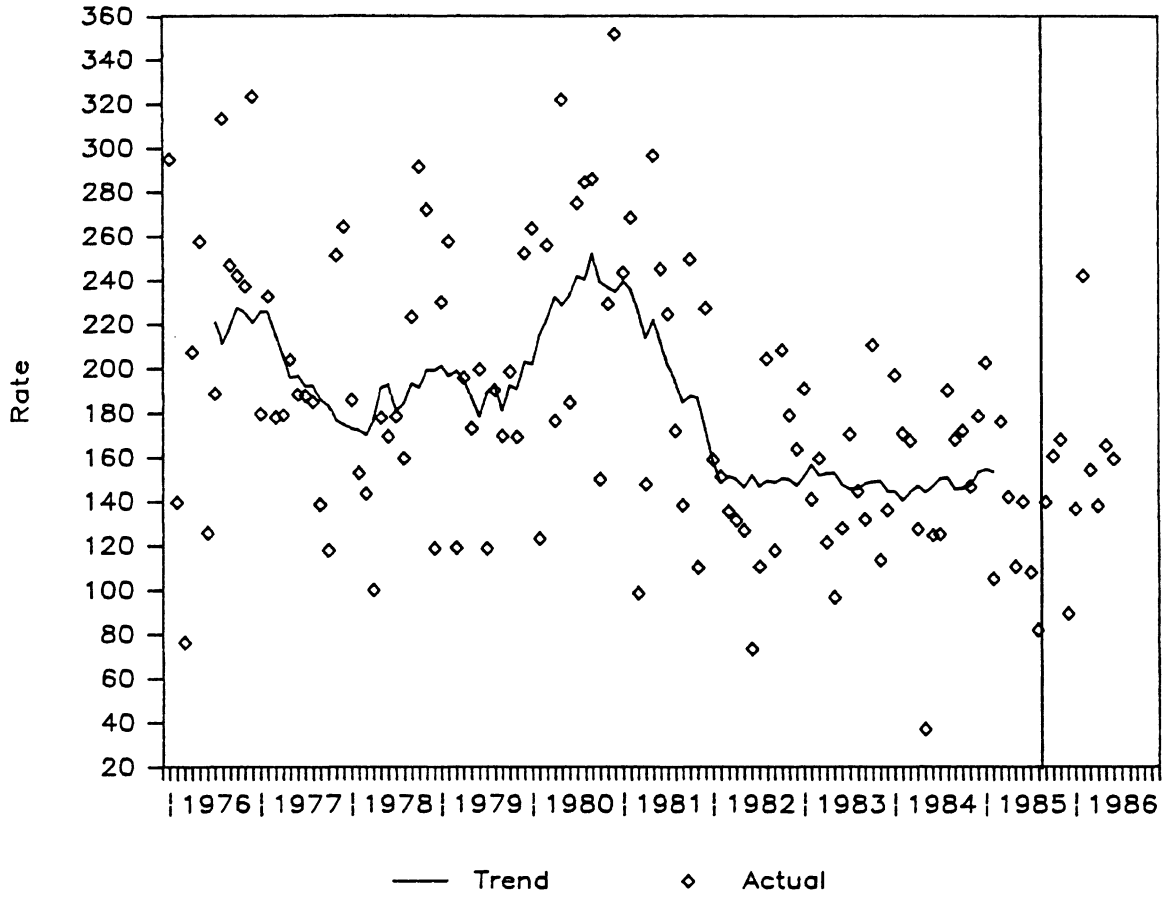

Figure A.6: Rate of Nebraska Front-seat Fatalities Age 10 and Over per 10 Billion VMT

Final Model

$$(1\text{-}B^{12})\, Ln Y_t = \underset{(.029)}{(1\text{-}.869B^{12})u_t} - \underset{(.059)}{(1\text{-}B^{12})\,.337X_{73}} + \underset{(.098)}{(1\text{-}B^{12})\,.076I_{117}}$$

Adjusted $R^2 = .23$

Effect of Nebraska seat belt law, September 1985-June 1986: +7.9%

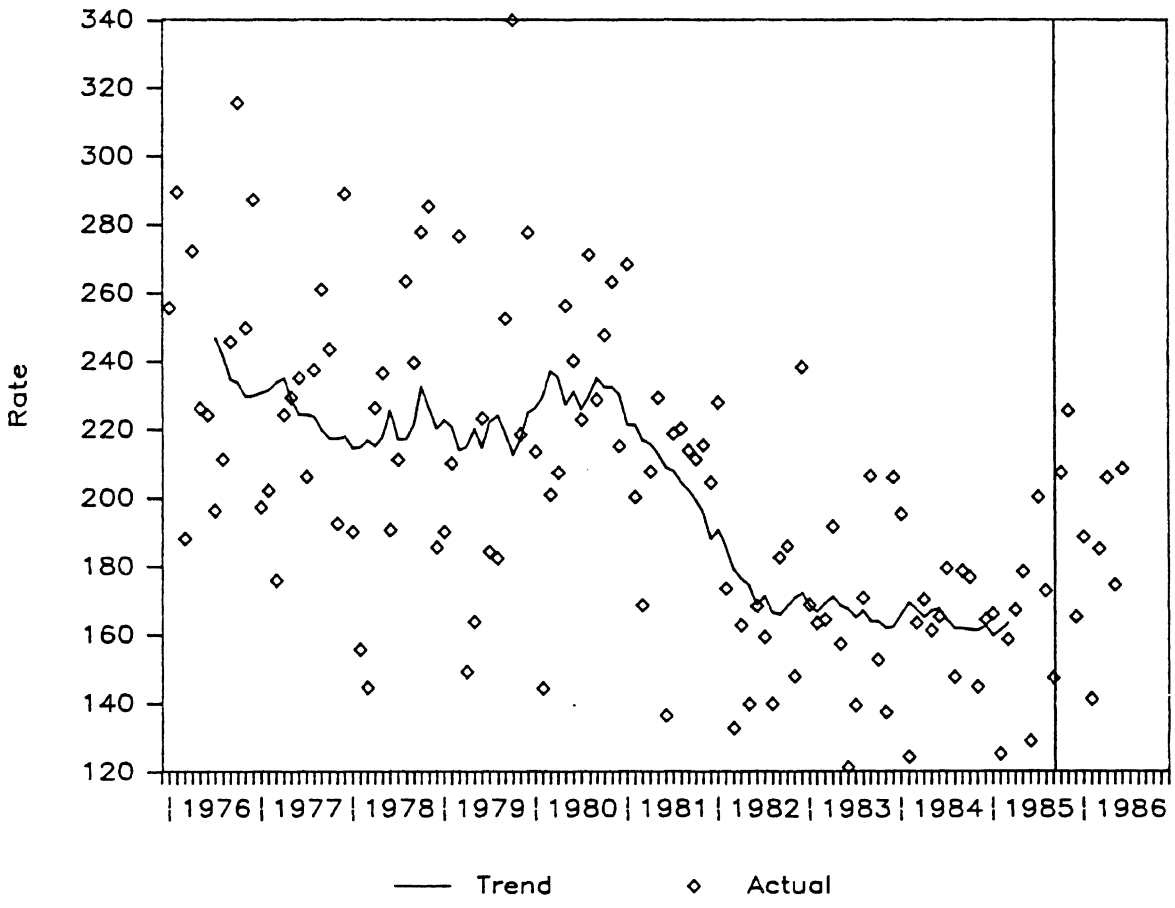

Figure A.7: Rate of Missouri Front-seat Fatalities Age 10 and Over per 10 Billion VMT

Final Model

$$(1\text{-}B^{12})\, Ln Y_t = (1\text{-}\underset{(.029)}{.881B^{12}})u_t - (1\text{-}B^{12})\underset{(.030)}{.288X_{73}} + (1\text{-}B^{12})\underset{(.052)}{.137I_{118}}$$

Adjusted $R^2 = .47$

Effect of Missouri seat belt law, October 1985-June 1986: +14.6%

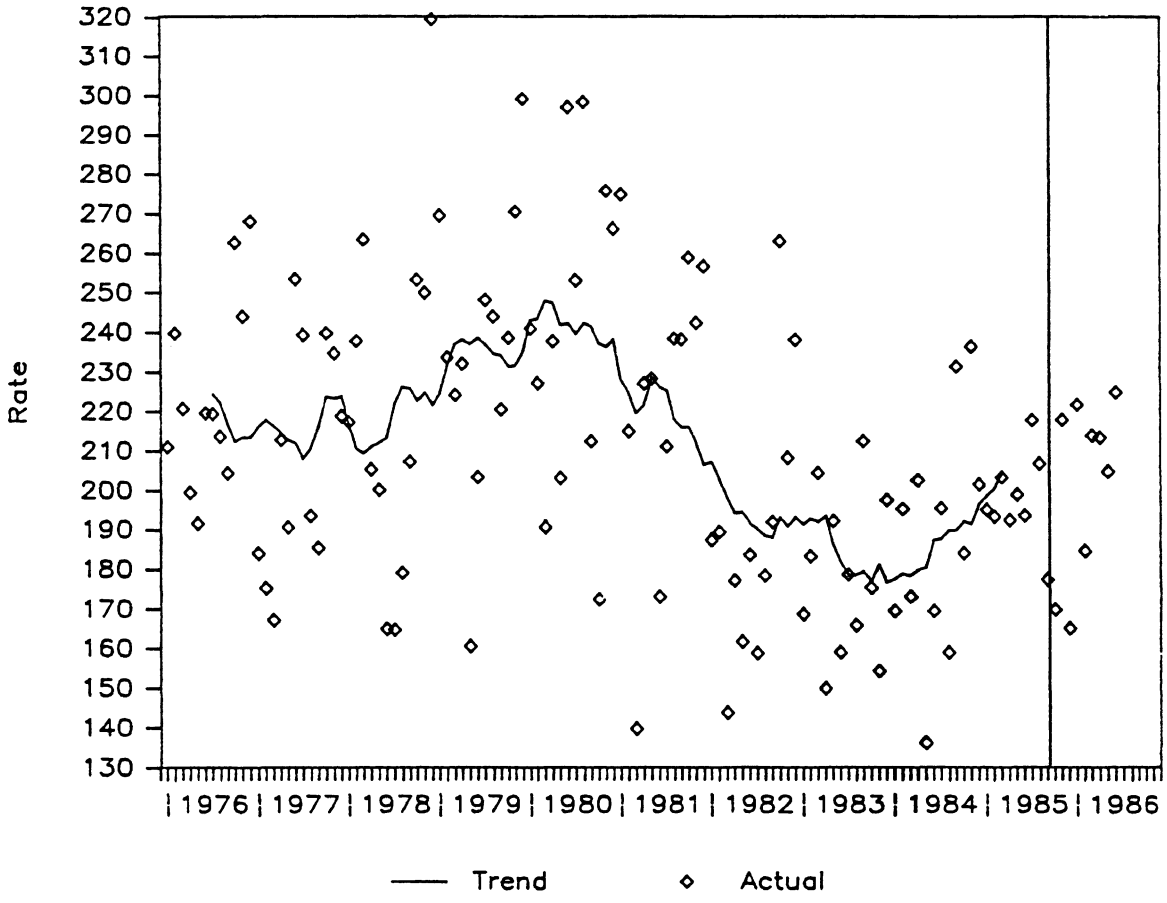

Figure A.8: Rate of North Carolina Front-seat Fatalities Age 10 and Over per 10 Billion VMT

Final Model

$$(1\text{-}B^{12})\, Ln Y_t = \underset{(.029)}{(1\text{-}.873B^{12})u_t} - \underset{(.029)}{(1\text{-}B^{12})\,.178X_{73}} + \underset{(.050)}{(1\text{-}B^{12})\,.063I_{118}}$$

Adjusted $R^2 = .23$

Effect of North Carolina seat belt law, October 1985-June 1986: +6.5%

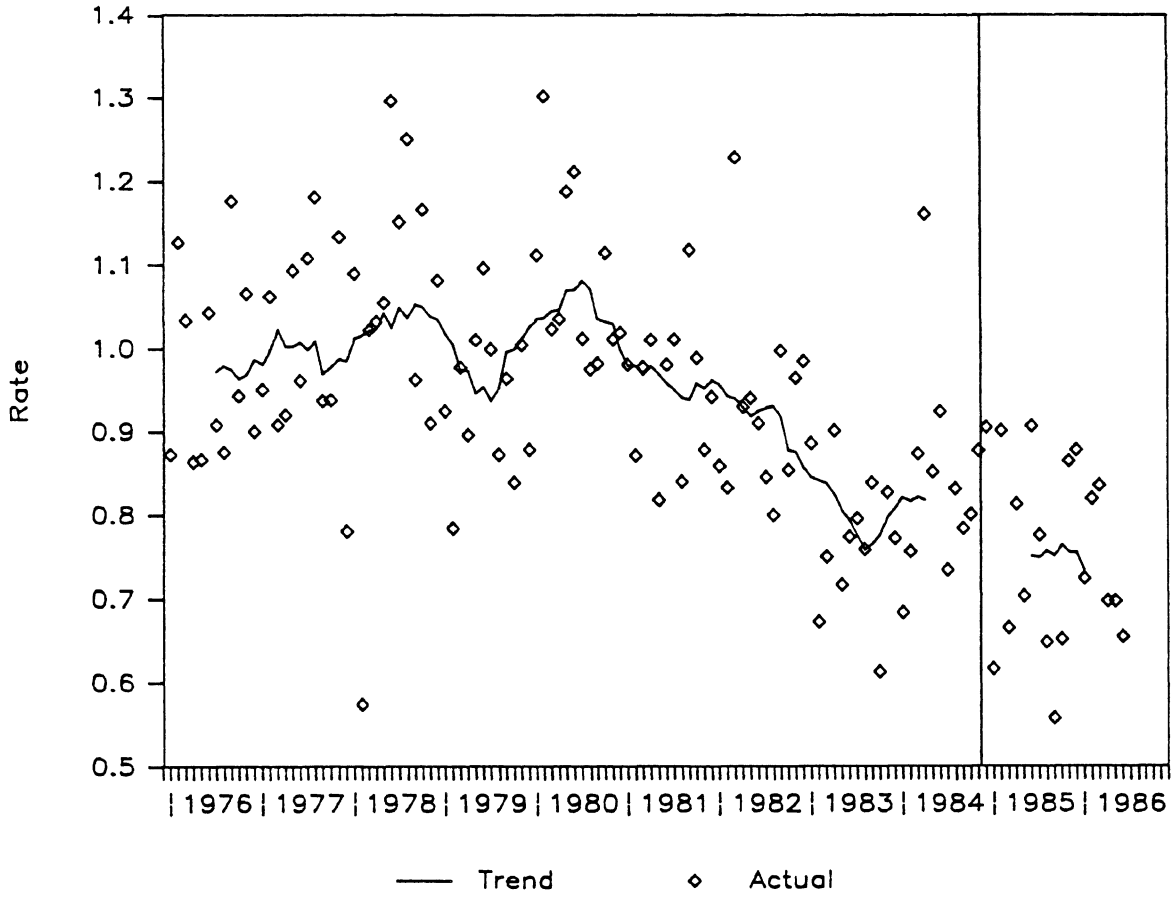

Figure A.9: Relative Rate of Front-seat Fatalities Age 10 and Over per VMT: New York versus Pennsylvania

Final Model

$$(1\text{-B})\, Ln Y_t = \underset{(.006)}{(1 - .981B)u_t} - \underset{(.035)}{(1\text{-B})\, .195X_{85}} - \underset{(.042)}{(1\text{-B})\, .073I_{108}}$$

Adjusted $R^2 = .40$

Effect of New York Seat Belt Law, December 1984-June 1986: -7.1%*

* $p<0.05$, one-tailed test.

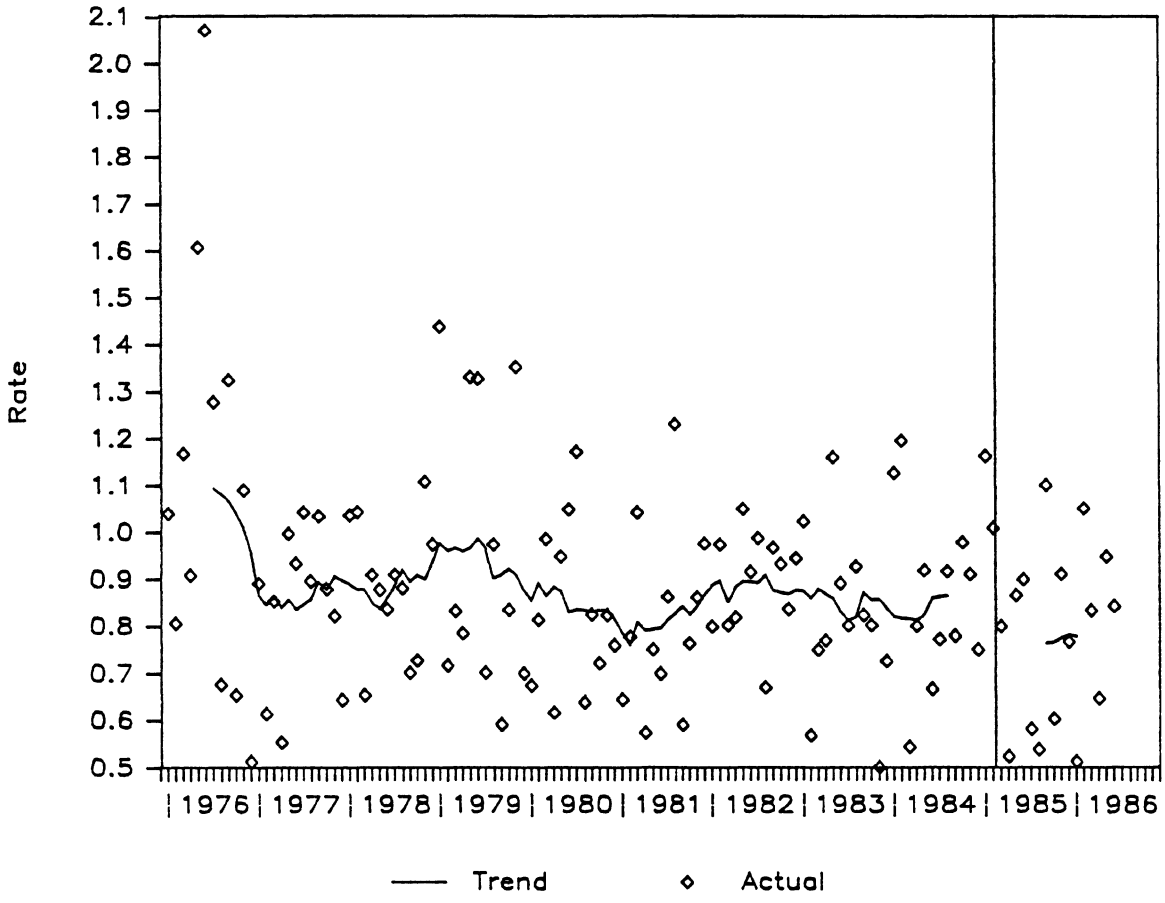

Figure A.10: Relative Rate of Front-seat Fatalities Age 10 and Over per VMT: New Jersey versus Maryland

Final Model

$$LnY_t = u_t - \underset{(.070)}{.281}I_{111}$$

Adjusted $R^2 = .25$

Effect of New Jersey seat belt law, March 1985-June 1986: -24.5%*

* $p<0.05$, one-tailed test.

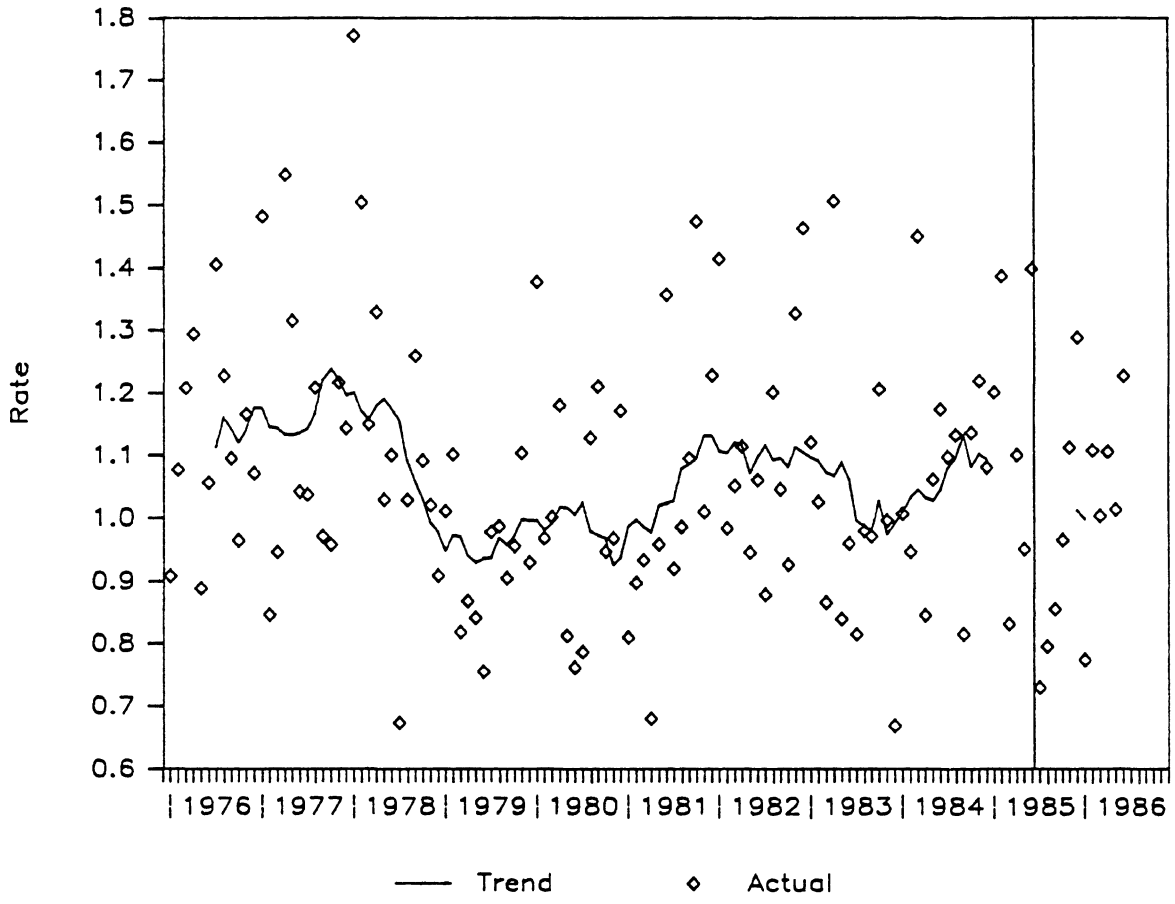

Figure A.11: Relative Rate of Front-seat Fatalities Age 10 and Over per VMT: Michigan versus Ohio

Final Model

$$LnY_t = u_t - .042I_{115}$$
$$(.062)$$

Adjusted $R^2 = .06$

Effect of Michigan seat belt law, July 1985-June 1986: -4.1%

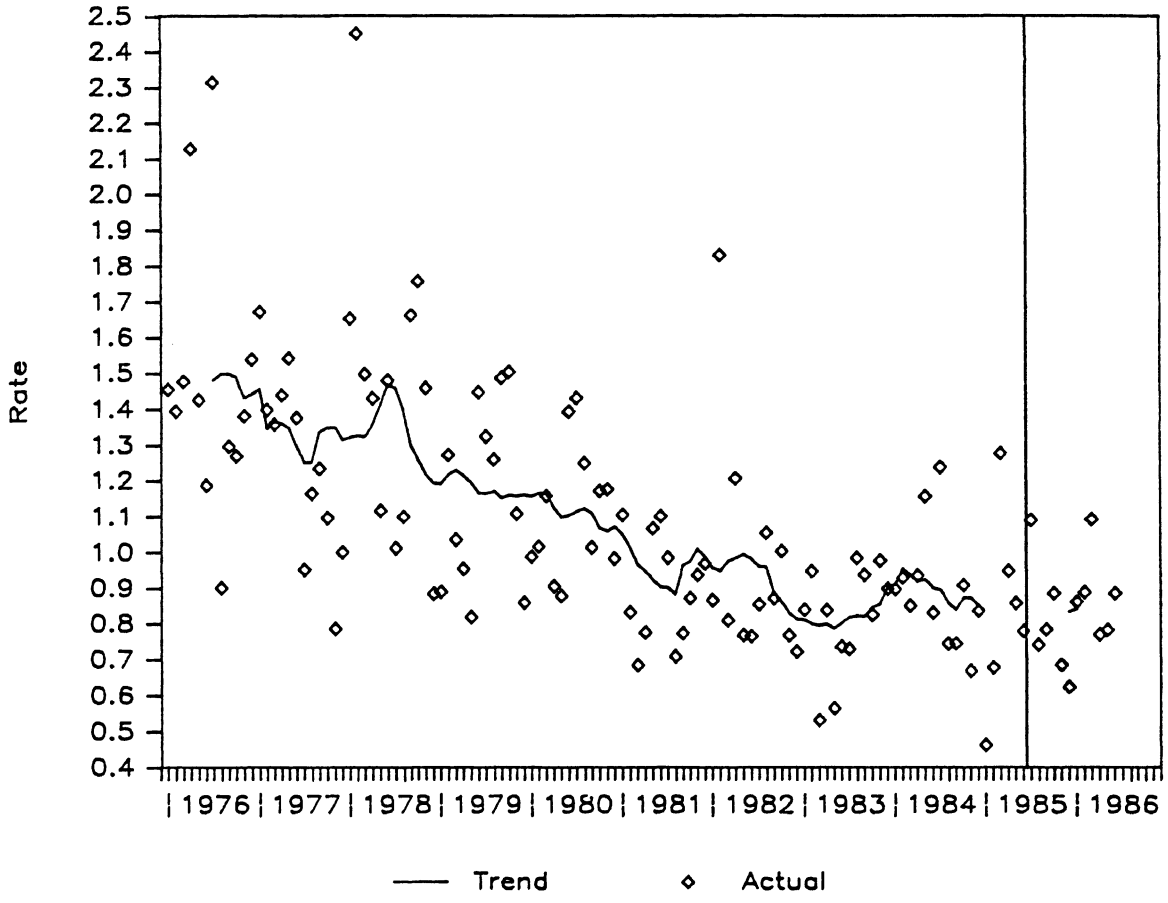

Figure A.12: Relative Rate of Front-seat Fatalities Age 10 and Over per VMT: Illinois versus Indiana

Final Model

$$(1\text{-}B)\,Ln Y_t = \underset{(.029)}{1\text{-}.937B)u_t} - \underset{(.088)}{(1\text{-}B)\,.265X_{61}} - \underset{(.092)}{(1\text{-}B)\,.015I_{115}}$$

Adjusted $R^2 = .40$

Effect of Illinois seat belt law, July 1985-June 1986: -1.5%

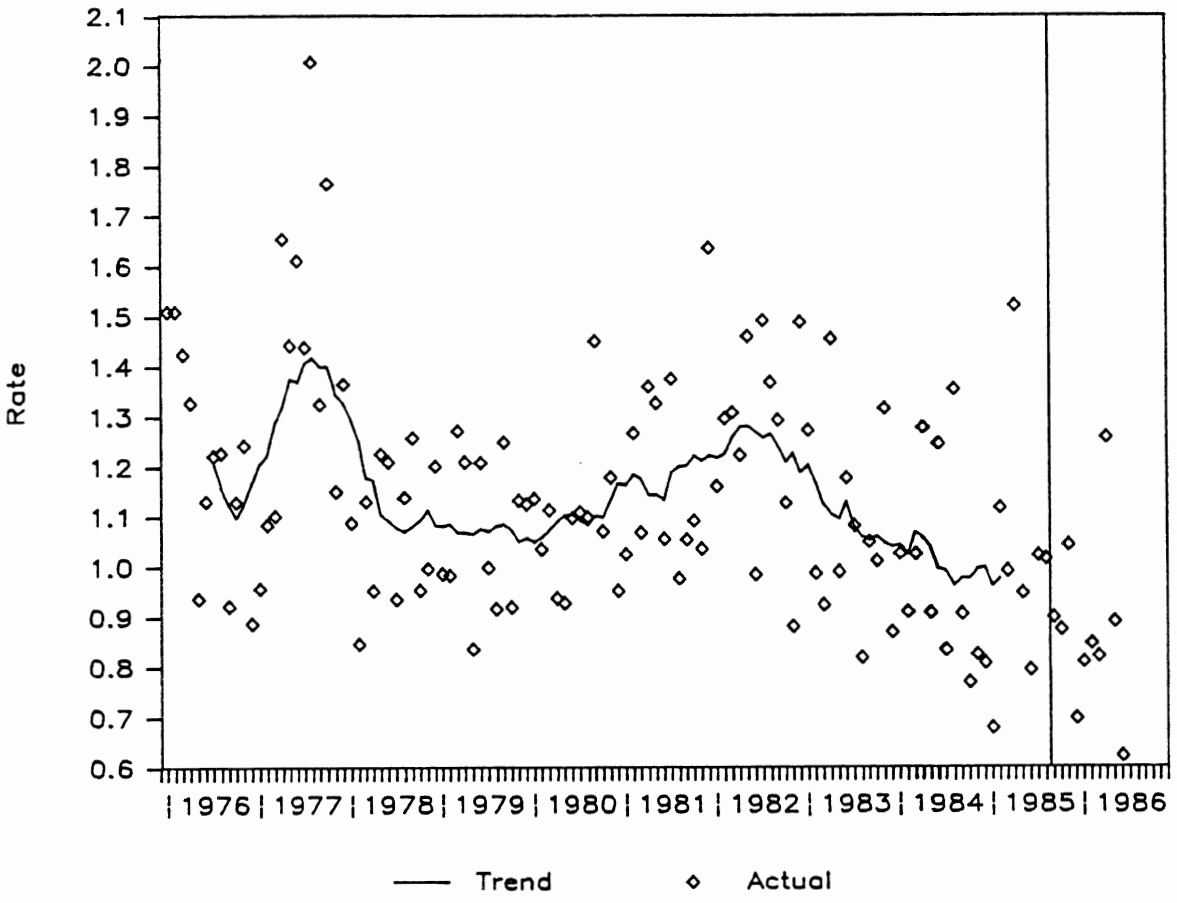

Figure A.13: Relative Rate of Front-seat Fatalities Age 10 and Over per VMT: Texas versus Georgia

Final Model

$$(1\text{-}B)\, Ln Y_t = \underset{(.045)}{(1\text{-}.860B)u_t} - \underset{(.099)}{(1\text{-}B)\, .123 I_{117}}$$

Adjusted $R^2 = .18$

Effect of Texas seat belt law, September 1985-June 1986: -11.6%

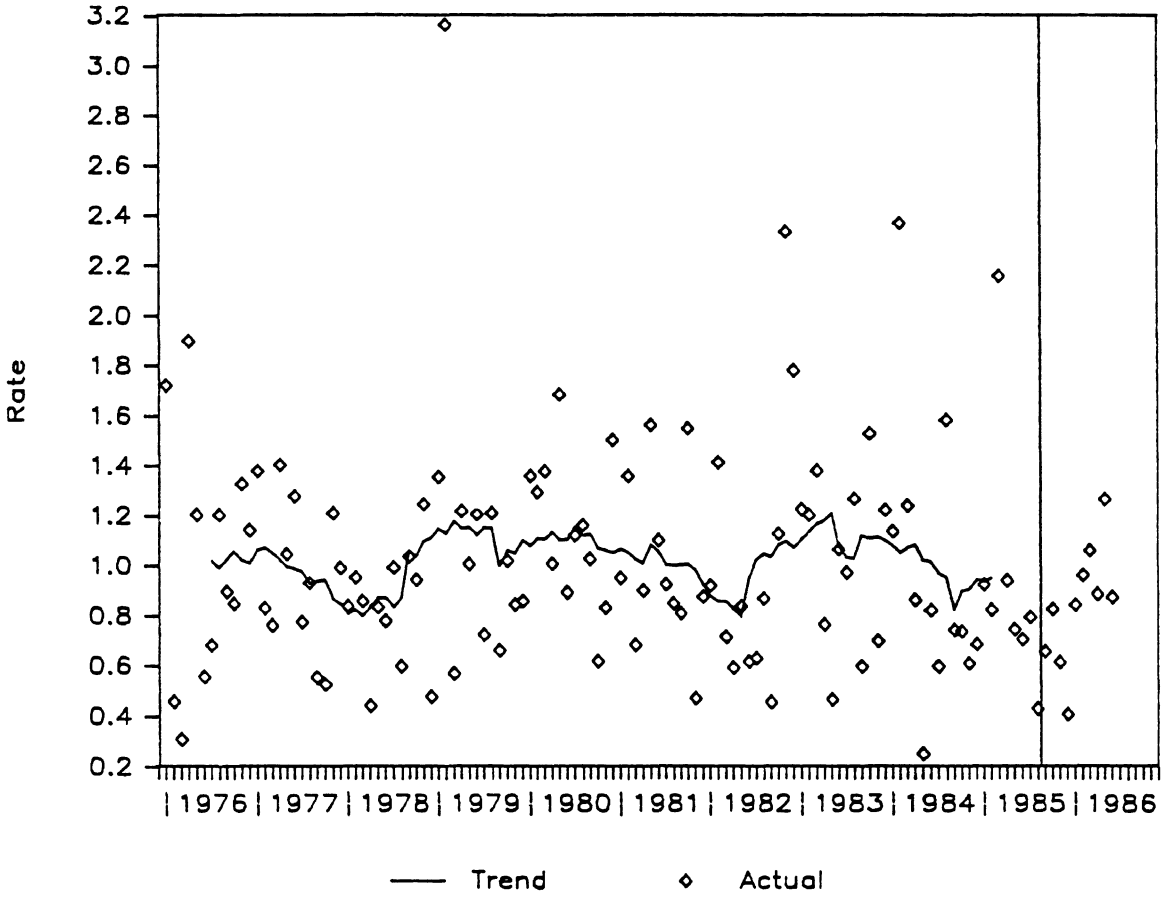

Figure A.14: Relative Rate of Front-seat Fatalities Age 10 and Over per VMT: Nebraska versus Kansas

Final Model

$$LnY_t = u_t - \underset{(.235)}{.471}P_{114\text{-}116} - \underset{(.129)}{.214}I_{117}$$

Adjusted $R^2 = .01$

Effect of Nebraska seat belt law, September 1985-June 1986: -19.3%*

* $p<0.10$, one-tailed test.

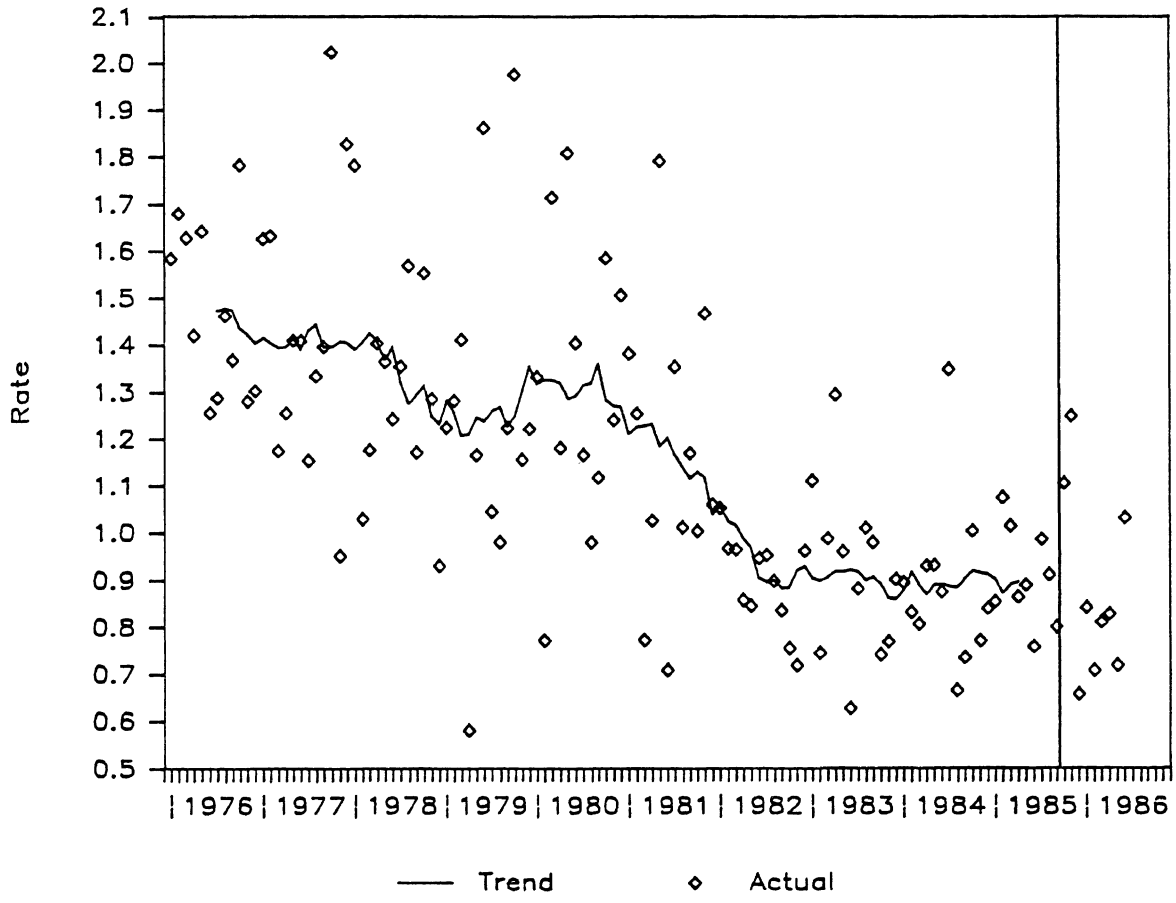

Figure A.15: Relative Rate of Front-seat Fatalities Age 10 and Over per VMT: Missouri versus Tennessee

Final Model

$$(1-B^{12})\,Ln Y_t = \underset{(.031)}{(1-.882B^{12})}\underset{(.093)}{(1+.176B^{7})}u_t - \underset{(.046)}{(1-B^{12})\,.356X_{73}} - \underset{(.077)}{(1-B^{12})\,.045I_{118}}$$

Adjusted $R^2 = .43$

Effect of Missouri seat belt law, October 1985-June 1986: -4.4%

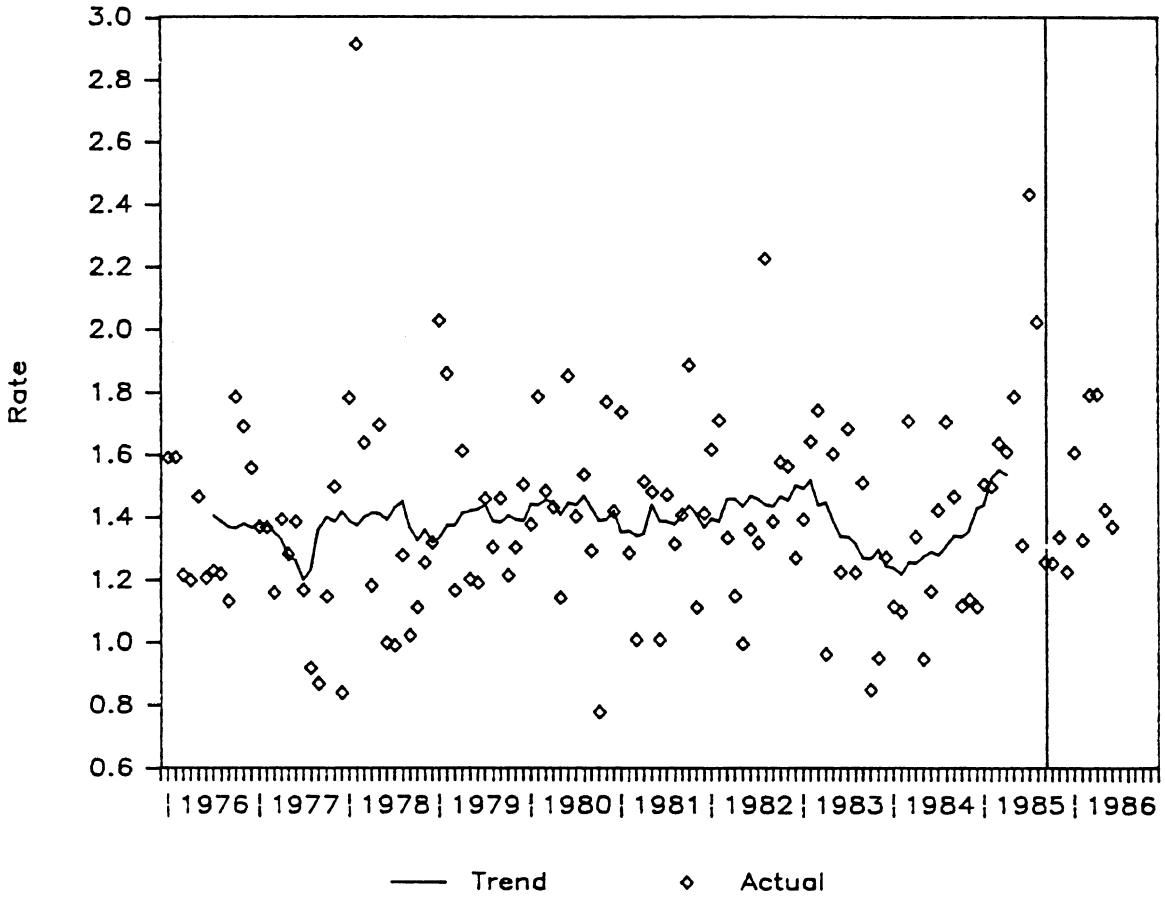

Figure A.16: Relative Rate of Front-seat Fatalities Age 10 and Over per VMT: North Carolina versus Virginia

Final Model

$$(1\text{-B})\, Ln Y_t = \underset{(.004)}{(1 - .992B)u_t} + \underset{(.063)}{(1\text{-B})\, .046 I_{118}}$$

Adjusted $R^2 = .02$

Effect of North Carolina seat belt law, October 1985-June 1986: +4.7%

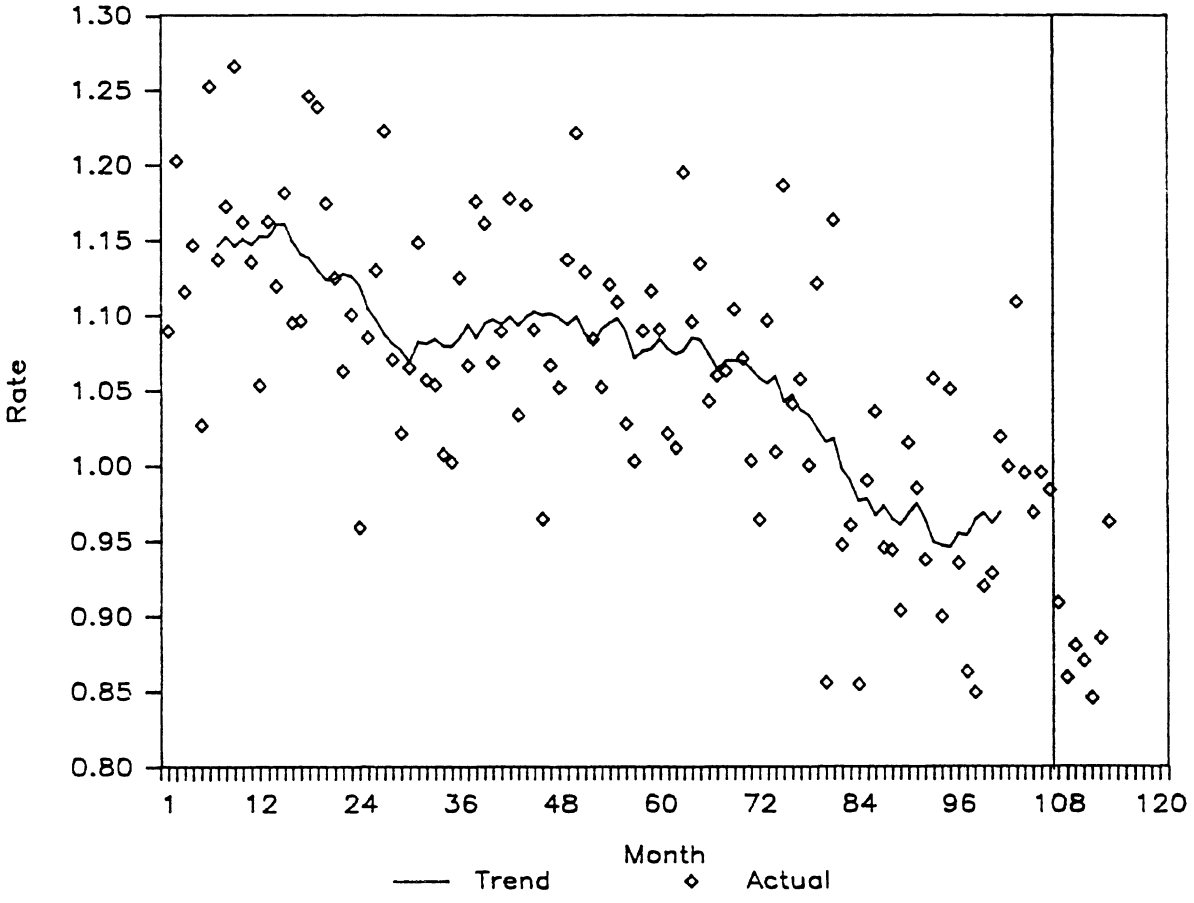

Figure A.17: Aggregate Relative Rate of Front-seat Fatalities Age 10 and Over per VMT for Eight Belt-law versus Eight Comparison States

Final Model

$$(1\text{-}B)\, Ln Y_t = \underset{}{(1 - .857B - .089^3)u_t} - \underset{(.075)\ (.079)}{(1\text{-}B)\ .098X_{79}} - \underset{(.028)}{(1\text{-}B)\ .091I_{108}} \quad \underset{(.034)}{}$$

Adjusted $R^2 = .51$

Aggregate effect of seat belt laws, eight post-law months: -8.7%*

* $p<0.05$, one-tailed test.

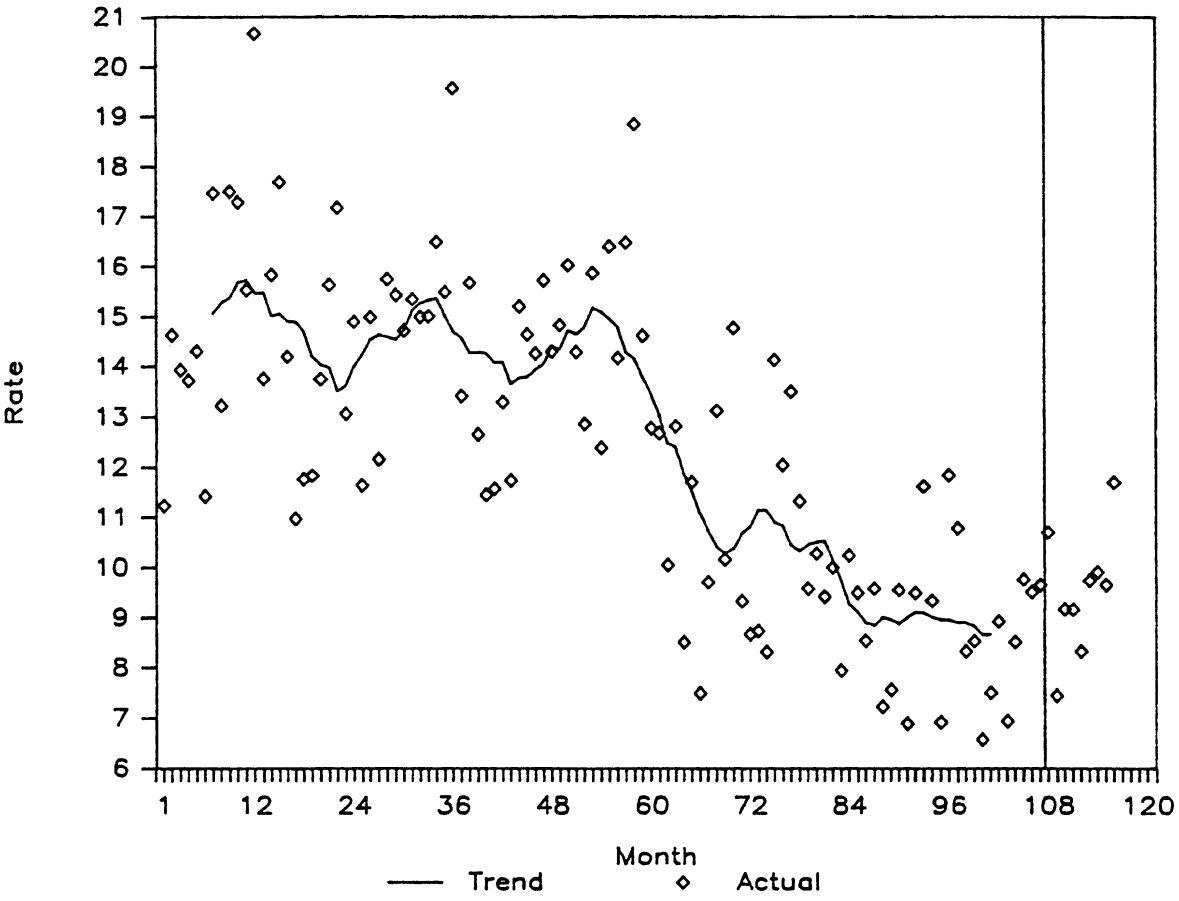

Figure A.18: Aggregate Rate of Rear-seat Fatalities Age 10 and Over per VMT for Eight Belt-law States

Final Model

$$(1\text{-}B)\, Ln Y_t = \underset{(.091)}{(1+ .259B^{12})}\ \underset{(.062)\ (.072)}{(1- .665B - .307B^{4})}\ u_t - \underset{(.069)}{(1\text{-}B)\ .366X_{60}} - \underset{(.093)}{(1\text{-}B)\ .009I_{108}}$$

Adjusted $R^2 = .67$

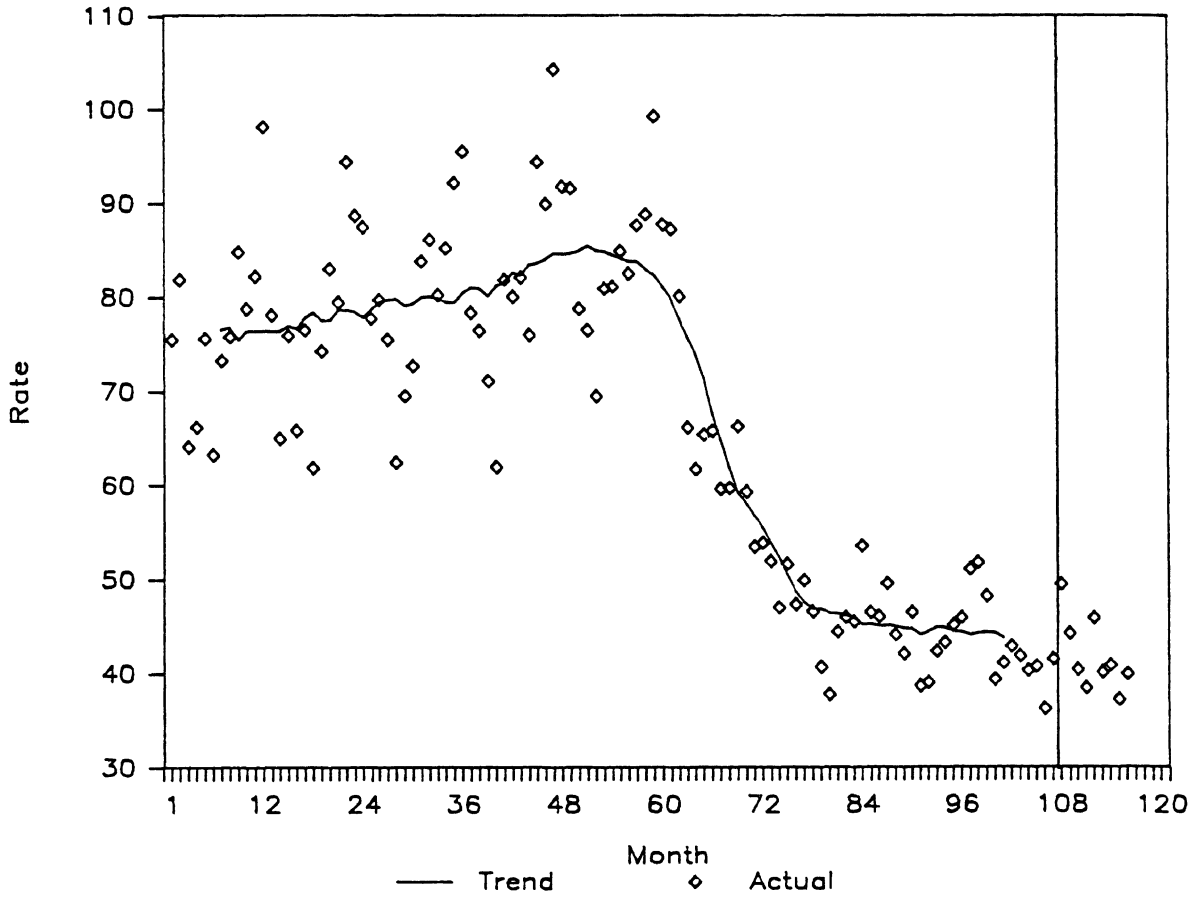

Figure A.19: Aggregate Rate of Nonoccupant Fatalities Age 10 and Over per VMT for Eight Belt-law States

Final Model

$$(1\text{-}B)(1\text{-}B^{12})(1+\underset{(.081)}{.551}B^{12})\,(1+\underset{(.093)}{.347}B)\,LnY_t = (1+\underset{(.081)}{.551}B^{12})\,(1+\underset{(.093)}{.347}B)u_t$$

$$-\,(1\text{-}B)(1\text{-}B^{12})\,\underset{(.085)}{.062}X_{62} + (1\text{-}B)(1\text{-}B^{12})\,\underset{(.103)}{.090}I_{108}$$

Adjusted $R^2 = .87$

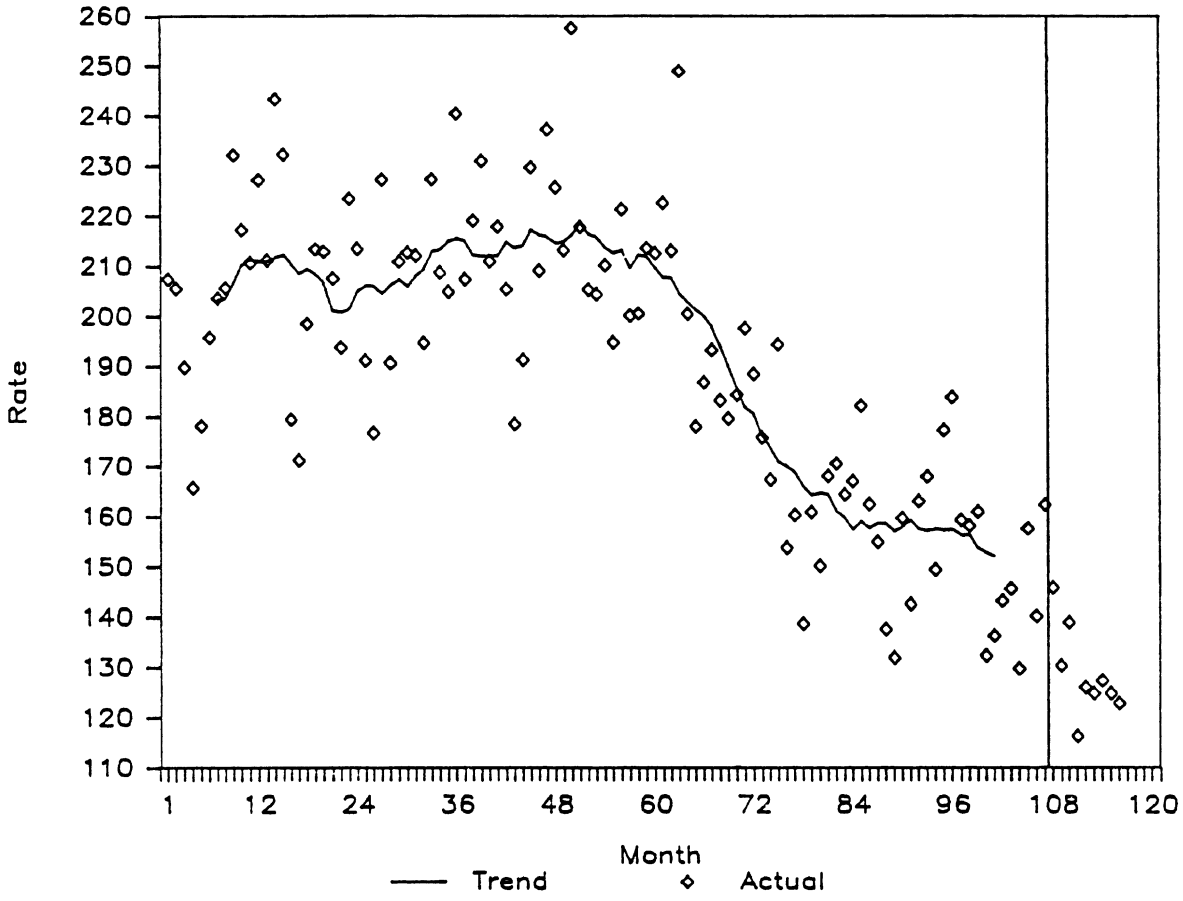

Figure A.20: Aggregate Rate of Front-seat Fatalities Age 10 and Over per VMT for Two Primary Enforcement Provision States†

Final Model

$$(1-B)(1-B^{12})\,LnY_t = \underset{(.033)}{(1-.873B^{12})}\ \underset{(.068)}{(1-.713B)u_t} - (1-B)(1-B^{12})\ \underset{(.052)}{.104I_{108}}$$

Adjusted $R^2 = .81$

Effect of primary states' seat belt laws, eight post-law months: -9.9%*

* $p<0.05$, one-tailed test.

† New York and Texas. North Carolina is not included as law not enforced until 1-1-87.

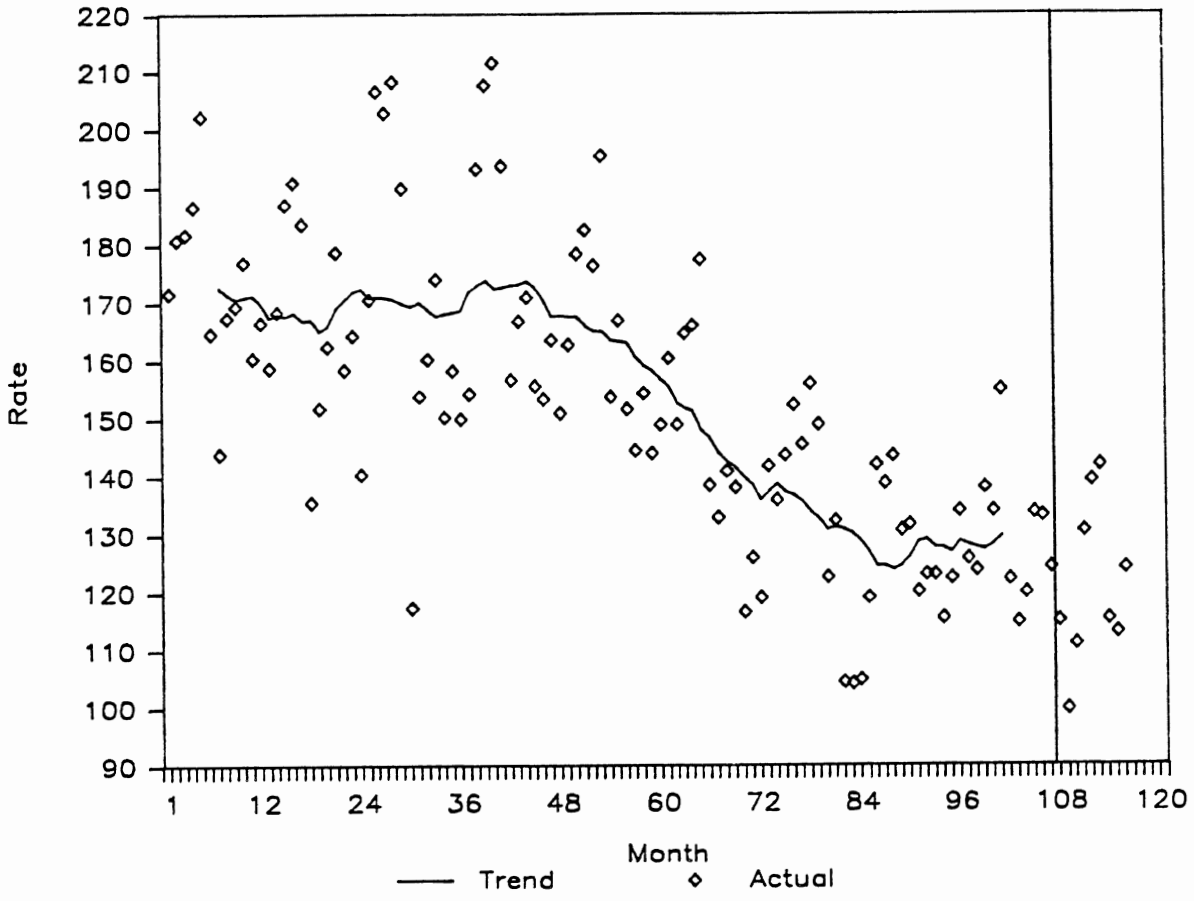

Figure A.21: Aggregate Rate of Front-seat Fatalities Age 10 and Over per VMT for Four Secondary Enforcement Provision States†

Final Model

$$(1-B^{12})\, Ln Y_t = \underset{(.097)}{(1+.228B)u_t} - \underset{(.034)}{(1-B^{12})\,.144X_{66}} - \underset{(.039)}{(1-B^{12})\,.070I_{108}}$$

Adjusted $R^2 = .69$

Effect of secondary states' seat belt laws, eight post-law months: -6.8%*

† New Jersey, Michigan, Illinois and Nebraska. Missouri is not included as law not enforced until 7-1-87.

Appendix B

Review of the Literature

Effects of mandatory restraint laws have been the focus of much research over the past decade. Until recently, many of the studies of the adult seat belt laws were conducted outside the United States. U.S. jurisdictions began implementing adult belt laws in late 1984. Now that these laws have been in effect for some time, studies of U.S. adult restraint laws have begun to appear. These studies are generally based on observed use of restraint systems, although several have also examined the effects of restraint laws on crash-related fatalities.

A number of the earlier studies used nonrandom samples, inadequate control groups, and unclear data analysis methods. Also, compared to injuries, traffic fatalities in many jurisdictions are low in number with high levels of variability over time. Many of the statistical studies, particularly those that use data for a year or less, have small samples and hence are more subject to the effects of random variation. Therefore, results from any single study should not be the sole means of assessing the effects of restraint laws.

However, the pattern of findings across many studies, in diverse jurisdictions, using various methods, and conducted during different periods, supports the proposition that mandatory restraint laws can significantly increase the proportion of motor vehicle occupants who regularly use restraints, and so prevent injuries and deaths in motor vehicle crashes.

This review will first examine adult seat belt laws in countries outside the United States, followed by a review of studies completed within U.S. jurisdictions. Literature on effects of child restraint laws has been reviewed elsewhere (Wagenaar and Webster, 1986; Wagenaar, Webster, and Maybee, in press).

B.1 Australia

The province of **Victoria** was the first to implement an adult mandatory restraint use law. On December 22, 1970, belt use became compulsory for motor vehicle occupants over the age of seven years.

Foldvary and Lane (1974) evaluated the seat belt legislation in Victoria based on a pre- and post-law comparison of crash data for the first nine months of 1970 and 1971. The fatality rate for vehicle occupants was compared to fatalities of other road users in Victoria and to the other Australian states, none of which had belt laws in effect during that time. The results in Victoria indicated a significant ($p \leq 0.05$) overall fatality reduction of 15%. In urban areas, which hold 66% of the population, the reduction was 21%; 10% reduction was observed in rural areas. The rest of Australia experienced a 1% fatality decline during this period. Two concomitant events were examined for possible influence on the results, namely a downward turn in the economy, and a year long road safety campaign by a widely circulated Victorian daily newspaper. The authors concluded that the effects of these factors were not statistically significant.

Trinca and Dooley (1977) examined traffic deaths in Victoria. An upward trend throughout the 1960s reversed in 1970 when the belt law was passed. According to these researchers, by 1974 deaths were 37% lower than in 1970. This casualty reduction was not accompanied by a similar reduction in the frequency of crashes, indicating that it was probably the result of increased seat belt use.

Vulcan (1977) summarized surveys conducted by Andreassend (1976) which indicated that belt use among Victorian drivers and front-seat passengers increased steadily from 1971 through 1976, from 32-48% in 1971 to 73-88% in 1976. Consistent with increased use, occupant fatalities were 32% lower than expected in 1976, given the 1960-1970 trends. In comparison, there were no appreciable changes in nonoccupant (i.e., pedestrian, motorcyclist) traffic fatalities during the same period. Vulcan notes that

other factors, such as December, 1972, and December, 1973, reductions in speed limit, also contributed to casualty reductions.

Joubert (1979) reports that belt use was about 18% before the law in Victoria. It increased after the law to 75% in urban areas and 64% in rural areas. Belt use continued to increase, reaching over 90% in urban areas and 80% in rural areas by 1978.

Joubert also examined occupant fatalities and injuries for 1971, the first year with the new law. Fatalities were down 15% among drivers and 19% among passengers. There was no decrease in fatalities for the rest of Australia, indicating that the reductions in Victoria probably resulted from the seat belt law.

Manders (1984) conducted a survey in Melbourne, March of 1984; overall belt use was found to be 85.3%. Drivers had the highest use rate, 95.9%, followed by front-seat passengers, with 92.1% belted. Seat belt use was highest on local (89.1%) and "peak-hour" trips (87.6%), and lowest after midnight (68.3%; Manders, 1984).

Trinca (1984) reports that the death rate in Victoria has declined steadily since implementation of the seat belt law. The rate has fallen from 8.1 deaths per 10,000 registered vehicles in 1970 to 3.4 deaths per 10,000 vehicles in 1982; for vehicle occupants the fatality rate was 2.2 per 10,000 vehicles in 1982. Pedestrian and motorcyclist deaths have also declined, but not as much.

Queensland mandated adult seat belt use beginning January 1, 1972. Seeney (1977) notes that traffic surveys in Queensland in 1972 indicated that the seat belt wearing rate for drivers immediately rose to about 60% after the compulsory belt use law was implemented. Moreover, in the 65% of vehicles with belts available, 90% of drivers were restrained. Further details were not provided.

Bhattacharyya and Layton (1979) conducted perhaps the most sophisticated analyses of Australian seat belt laws, focusing on Queensland. They used Box-Jenkins time-series modeling to establish that motor vehicle occupant deaths in the mid-1970s were 46% less than expected without the belt law.[4] Exposure to the risk of crash, as measured by gasoline sales, was controlled in the analyses, increasing confidence that the observed effect resulted from the seat belt law. Two remaining confounding factors are the reduction in speed limit and significant improvements in traffic control during the 1970s (e.g., installation of traffic lights and stop signs).

Crinion and others (1975) analyzed the effects of **South Australia's** seat belt law, which became effective in November, 1971. Based on an annual survey of seat belt use in Adelaide, the overall wearing rate went from 22.7% just prior to implementation to 48.9% in October, 1972. However, for those with belts available, the use rate was 77.8%. After comparing fatality data for the first year of the law with the year before implementation, the authors concluded that occupant fatalities dropped 7.5% overall. This decline occurred entirely in vehicles first registered after 1966 when seat belt installation was mandatory.

Johinke (1977) reports belt use before the law increased from 8% in 1964 to 23% in 1971. With minimal enforcement after the law took effect, use increased to 49% overall, and 78% for occupants with belts available. Increased enforcement in 1976 resulted in 90% restraint use for drivers with belts available. According to Johinke, the enhanced enforcement efforts were also associated with a reduction in occupant fatalities of 14%.

In November, 1982 a roadside survey was done in the Adelaide Metropolitan Area following a public education campaign on seat belt use. The results indicated that use was 91% for drivers, 85% for

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4. By using the Box-Jenkins approach, which explicitly takes into account serial correlation in time series, Bhattacharyya and Layton avoided the error made by McDermott and Hough.

front-seat passengers, and 61% for rear seat occupants with belts available (Road Traffic Board of South Australia, 1983).

New South Wales instituted compulsory seat belt use for occupants of passenger cars in October, 1971. Surveys of occupant restraint use indicate that restraint use increased from 30% to 75% within six months after the law was implemented (Schnerring, 1983). Rates of belt use gradually increased until 1976 and then declined slightly for five years. The 1981 survey reported belt use rates of 85% for drivers and 75% for front-seat passengers in the metropolitan Sydney area. Belt use was lower in rural areas, with about 76% of drivers restrained.

McDermott and Hough (1979) examined the numbers of annual traffic fatalities in the whole of Australia from 1955 through 1977. Beginning with Victoria, all Australian provinces implemented mandatory restraint laws in the early 1970s. During this period there was a significant decline in the rate of motor vehicle occupant deaths per registered vehicle.[5] Although the speed limit reduction and fuel shortages of the early 1970s were contributing factors, there were no comparable reductions in fatalities among motorcyclists and pedestrians. Thus it is likely that the restraint law caused observed reductions.

Fisher (1980) reviewed the effects of Australian belt laws and concluded that use rates increased from about 25-35% before the laws were implemented to 74-95% immediately after, with a partial decrease of the laws' effects over time. After noting that methodological details for many studies were not available, Fisher concluded that there was a reduction of about 20% in occupant fatalities after compulsory belt laws were implemented in Australia.

B.2 Austria

Austria implemented a mandatory belt use law for front-seat occupants in July, 1976. Although the law had no penalty for noncompliance, belt use increased (Fisher, 1980). According to Marburger (1986), usage rates prior to legislation were 5-10% in urban areas, and 20-25% in rural areas. Subsequent to implementation of the law, use rose to 10-15% in urban areas and 40% in rural areas. In July, 1984 the law was amended such that fines were imposed for noncompliance. A national survey done in September, 1984 reported usage rates of 81% in urban areas, 82% in rural areas, and 86% on expressways. In August, 1985 a survey showed wearing rates were virtually unchanged.

B.3 Belgium

Belgium enacted a compulsory seat belt law for front-seat occupants in June, 1975 (Fisher, 1980). Fisher (1980) obtained a document that indicated use of about 17% before the law, increasing to about 87% after. However, after that initial increase, belt use gradually decreased. The most recent report reveals belt usage in November, 1984 was 70% in rural areas and 60% in urban areas (Marburger, 1986). Consistent with the increased belt use after the law was enacted, occupant fatalities decreased 25%, according to Fisher.

B.4 Canada

Among drivers in **British Columbia**, belt use increased from 20-24% before the October 1977 mandatory use law to just over 50% after (Rockerbie, 1983). Box-Jenkins intervention analyses of occupant fatalities indicated a significant decrease beginning nine months after the law was implemented,

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5. Determination of the statistically significant decline is based on deviations from linear trends based on ordinary least squares regression. Because the assumption of uncorrelated residual errors was violated, the measure of statistical significance is suspect, and results should be interpreted cautiously.

provided the pattern of fatalities in the mid-1970s was assumed to represent a long-term upward trend. Under a model assuming no long-term trend, no significant effect of the law on fatalities was found. Because a significant fatality reduction was found only with a model that included a trend component and a nine-month lag, and not with several other models tested, these findings offer only tentative evidence that the restraint law may have reduced traffic fatalities.

More recent observational studies report higher usage rates than the earlier surveys. A provincial survey conducted by B.C. Research (1983) in April of 1983, found 55% of vehicle occupants belted. This figure rose to 67% by June of 1983 following a province-wide program of public education to promote belt use, coupled with police enforcement. An independent survey completed during November, 1983, reports belt use in British Columbia of 67.4% (Arora, 1985).

Jonah and Lawson (1984) analyzed British Columbia traffic crash data for the years 1960-1981. Regression analyses were used to predict expected fatality rates based on pre-law trends. Results indicated significant ($p \leq 0.01$) fatality reduction in each of the four post-law years studied. A second analysis compared occupant and nonoccupant fatality rates from 1971 to 1981. The results indicated that while there was a 0.2% increase in occupant fatalities, nonoccupant fatalities rose 14.4% during those years.

Hedlund (1986) examined eleven years of British Columbia fatality data, six years before the law and the first five years after. Nonoccupant fatalities were used to determine the expected number of occupant fatalities without the belt law. The author concluded that the seat belt law has resulted in a 52% reduction in occupant fatalities.

New Brunswick instituted a mandatory seat belt law in September, 1983. Arora (1985) reports that belt use by drivers increased from 4.2% in 1982 to 66.5% in November, 1983. In August, 1984 a province-wide survey was conducted by the New Brunswick Department of Transport (1984), which indicated 73.2% of motorists were belted.

Newfoundland has had a seat belt law in effect since July, 1982. The pre-law usage rate was 8.6% overall, with use on rural roads slightly higher at 9.1%, (Arora, 1982). One year after implementation of the belt law, seat belt use in Newfoundland was 67.8% In November, 1983, two years after the Newfoundland law took effect, use in urban areas was 75.9%, and in rural areas 60.7% (Arora, 1985). A survey in July, 1984 found an overall belt use rate of 73.9% (Murray, 1984).

In **Manitoba**, seat belt legislation took effect in January, 1984. In November 1983 prior to implementation of the law, belt use was 11.1% (Arora, 1985). The provincial government conducted a survey in June, 1984 which found driver belt use to be 79.1% (DataCom, 1984). This survey was conducted primarily in urban areas, however, and the results may not be indicative of seat belt use rates throughout the province. A survey in November, 1984 found an overall use rate of 61.6% in Manitoba (cited by Jonah and Lawson, 1986).

Snow (1979) reviewed belt use in **Ontario** in the 1970s, pointing out that use was about 10-15% in the early 1970s, rising to 17% by 1975. These slight increases occurred during a period characterized by mass media campaigns to encourage belt use. In December, 1975, immediately before the January 1, 1976 implementation of a mandatory belt law, use rose to 21%. After the law took effect, use jumped to 77% in February, 1976, and then declined to just over 50% by June of that year. Snow reported a 13% reduction in fatalities in Ontario over the first six months of the new law. It should be noted, however, that a simultaneous reduction in the province-wide speed limit makes it impossible to attribute the observed fatality declines solely to the restraint law. Pierce (1979) reported usage figures similar to Snow, with the addition of a survey of drivers in May 1978, which revealed that use was up to 65%. The increased use seen in 1978 may have resulted from the strengthened enforcement that began in mid-1977.

Simpson and Warren (1981) reviewed the effects of Canadian mandatory seat belt laws on belt use and casualty rates. The authors concluded that decreasing compliance observed in mid-1976 was a result of the driving public gradually becoming aware of the low risk of detection and punishment for

violating the belt law. Robertson (1978) argues that the weakening of the law two months after it was implemented to exclude shoulder belt use in pre-1974 cars was perceived by the public as a signal that the government was retreating from a strict law. A simple pre-to post-law comparison showed a 16% decline in vehicle occupant deaths in 1976 compared to 1975, however, pedestrian deaths declined 15% during the same period. Robertson concluded the speed limit reductions or factors other than seat belt use were responsible for the observed reductions. Simpson and Warren reached a similar conclusion, stating that although seat belt legislation in Ontario was effective in reducing vehicle occupant injuries, its effect on fatalities was limited.

Matthews (1982) observed belt use by Ontario drivers from September to December, 1980. Belt use averaged 49% during this period. Matthews points out that this figure is close to the 50% estimate found in May, 1977 after the law had been in effect for a year (Pierce and others, 1979), indicating that belt use may have been stabilizing after the temporary increase in early 1976 and subsequent decrease during the following several months.

Jonah and Lawson (1984) analyzed the effects of Ontario's seat belt law on fatalities for the first six years of the law. Expected fatality rates were estimated by regression analyses, which used crash data for 1960 through 1975 to predict fatality rates for the post-law period. Results indicated significant declines ($p \leq 0.10$ in 1976; $p \leq 0.01$ in 1977 and 1978; $p \leq 0.05$ in 1980 and 1981) in each of the six years. McCarthy and others (1984) reported a 24% post-law fatality reduction in Ontario using vehicle miles traveled as a control.

Arora (1985) reported the results of observational surveys conducted in 1982 and 1983. Belt use by drivers increased from 48.9% in 1982 to 60.1% in 1983. A survey cited by Jonah and Lawson (1986) found driver usage to be 70% in May, 1984. Both of these surveys used multi-stage sampling plans designed to represent travel on all road types during daylight hours. The authors offered no explanations for these dramatic increases.

Quebec passed a mandatory seat belt law in August, 1976 for all occupants weighing more than 23 kg (the approximate weight of a five-year-old child). Results of an observational survey by Stulginskas and Pless (1983) suggest that restraint use by children age 5-11 increased steadily from 4% in 1976, to 18% in 1978, and to 41% in 1981. Drivers showed a similar trend in the use of seat belts, increasing from 15% before the law to 23% in 1981. However, the observations these estimates are based on were made at only one site near a large urban children's hospital. As a result, they may not represent most of Quebec's motorists.

In the annual observational survey reported by Arora (1985), driver restraint use in Quebec was 67.5% in November 1982, and 60.4% in November, 1983. A major province-wide observational survey was conducted in Quebec in June, 1983 (cited in Jonah and Lawson, 1986) found that belt use was higher on freeways than on urban streets for both drivers, 74% vs. 60%, and passengers, 66% vs. 52%.

Jonah and Lawson (1984) analyzed the effects of Quebec's mandatory seat belt law during its first five years (1976-1981). A regression line was plotted using the crash data from the years 1960-1975 to predict expected casualties in the post-law years. Post-law fatality rates per kilometer for all five years were within 95% confidence limits for the pre-law regression line. The authors concluded that the fatality rate in Quebec was no different after the law than it was before the law took effect. One reason for the observed lack of effects may be the relatively low rate of belt use, which peaked at 40% between 1976 and 1982.

Hedlund (1986) also examined effects of the seat belt law in Quebec using the same fatality data as Jonah and Lawson (1984). Hedlund compared the occupant fatality rate in the six Canadian provinces without belt laws for the years 1976-1981 to occupant fatalities in Quebec during those years. Results indicated 31% fewer occupant deaths in Quebec than would have been expected based on the fatalities in the non-law provinces. Hedlund also used nonoccupant fatalities for comparison, making the assumption

that without a law, the difference between occupant and nonoccupant fatalities would be the same in law and non-law provinces. Results showed an 18% fatality reduction associated with Quebec's belt law.

Although **Saskatchewan's** seat belt law became effective July 1, 1977, it was not actively enforced until October 1, 1977. The law resulted in an increase in belt use from 26% to 78% among drivers and from 24% to 80% among front-seat passengers (Simpson and Warren, 1981). Detailed data on use among front-seat occupants (both drivers and passengers) provided by Sheils (1978) were as follows: 24% in May, 1977; 65% in July, 1977; 73% in October, 1977; and 60% in May, 1978. Bergen and others (1979) observed driver belt use and reported the following figures: 52% in July, 1977; 70% in October, 1977; 55% in May, 1978; and 70% in May, 1979. Arora (1982, 1985) reported Saskatchewan driver restraint use of 56.1% in November, 1980; 48.6% in November, 1981; 48.4% in November, 1982; and 54% in November, 1983.

Sheils (1978) analyzed traffic fatalities for one year before and one year after implementation of Saskatchewan's seat belt law. Results indicated a 19.5% decline in the number of deaths in the first twelve months with the law compared to the same period of the previous year, despite the fact that the province experienced a 10% increase in the number of crashes during that time. Time-series analyses were also performed using the fatality figures for the twelve years from 1966 through the first half of 1978. Results showed a decrease in the number of deaths during the first six months of the law of 5.3%, and a 30% reduction for the first six months of 1978 from the number that would have been expected based on fatality trends of the previous twelve years. In a third model, fatality data for Saskatchewan were compared to two neighboring provinces, Manitoba and Alberta, which did not have seat belt laws in effect at the time. Fatalities in Saskatchewan increased slightly after the belt law was implemented, but the increase was less than expected, given previous trends, and was less than the increase in Alberta. On the other hand, fatalities declined in Manitoba, the second comparison province.

Jonah and Lawson (1984) also examined the effect of the Saskatchewan seat belt law. Using the fatality rates for the pre-law period, 1960-1976, a regression line was plotted through 1981. The actual post-law fatality count was then compared to the predicted rates. Results showed the fatality rates for the first three years of the post law period were within 95% confidence limits of the pre-law regression line. However fatality rates for 1980 were marginally lower ($p \leq 0.10$) and 1981 rates were significantly lower ($p \leq 0.05$) than the predicted rates. The authors also compared occupant and nonoccupant injuries for the post law period (1977-1981). While there was a slight increase in occupant fatalities (1.8%), nonoccupant fatalities rose 13.3% during this time. Hedlund (1986) used the same data to analyze the effects of Saskatchewan's seat belt law. Using nonoccupant fatalities for comparison, he reported that occupant fatalities for the years 1977-1981 were 29% lower than what would have been expected without a law.

B.5 Denmark

Denmark required front-seat occupants over the age of 14 to use restraints beginning January 1, 1976. According to information compiled by Marburger (1986), seat belt use increased from 19% prior to legislation to 74% following implementation of the seat belt law.

A report issued by the Nordic Traffic Safety Council (1984) states that front-seat occupant fatalities decreased 1% in the first year after the law. This was based on simple year-to-year comparisons and very small numbers (only 640 fatalities occurred during that two year period). However, overall car occupant fatalities increased 6% during the first year of the law, an indication that the law was responsible for the observed decline in front-seat occupant deaths.

Hedlund (1986) also analyzed the effectiveness of Denmark's seat belt law in the first year of implementation. Using other road user fatalities (all road users except front-seat car occupants) for comparison, he concluded there was a 13% reduction in front-seat occupant fatalities. Again, these calculations were based on a small number of occurances, and the author cautions that the results "should not be taken too seriously."

B.6 England

A mandatory seat belt law was implemented in England in February, 1983. A series of observational surveys at several sites in the Birmingham area documented a substantial rise in occupant restraint use following the law's implementation. Restraint use increased from 43% the month before the law to 95% eleven weeks after the law went into effect (Ashton and others, 1983).

Observational studies reported by Mackay (1984a, 1984b) showed that seat belt use rates remained at about 90% from January, 1983 through January, 1984. Analysis of the first eleven months of post-law casualty data indicated a decline of 25% for occupants of cars and light vans when compared with data from February-December of 1982. The 25% reduction in casualties is the exact level of effect expected with an assumed 41% technical effectiveness of seat belts and 90% compliance.[6] Since traffic mileage increased by about 1%, it appears that observed casualty reductions were largely attributable to the seat belt legislation.

Pye and Waters (1984) reviewed records of motor vehicle casualties at a large university hospital emergency room three months before and three months after England's seat belt law went into effect. The number of motor vehicle related deaths in this sample declined from 15 to three after the belt law was implemented ($p \leq 0.001$). However, because of limited sampling procedures, including only one hospital and a six-month observation period with no controls on seasonality, the findings should not be generalized to the total population affected by the law.[7]

The Department of Transport (1985) studied the effects of England's compulsory seat belt law for the first two years following implementation. Crash data from the months February, 1983 through January, 1985 were compared to the same period prior to the legislation. The figures indicated a substantial reduction in front-seat occupant deaths of about 470 per year. Since increases in both vehicle kilometers traveled and rear-seat occupant fatalities were noted, it would appear that the observed declines can be attributed to the restraint law.

Durbin and Harvey (1985) also examined the effects of two years of compulsory seat belt wearing in England. Time-series analyses were performed using crash data for the years 1979-1984, which included the first 23 months with the law, separately for different classes of traffic fatalities. For the car driver and car front-seat passenger categories, traffic volume and gas price values were included in the model as predictors. Results indicated an 18% reduction in the number of car drivers killed, and a 25% reduction in front-seat passengers killed. An estimated 511 drivers and 328 front-seat passengers were saved during these 23 months as a result of the belt law. Analyses of the other road user categories indicated fatality increases: rear-seat passenger deaths increased 27% ($p \leq 0.10$); bicyclist deaths increased 13%; pedestrian deaths increased 7.8% ($p \leq 0.10$). Given the observed reductions in front-seat occupant fatalities and concomitant increase in other road user fatalities, it appeared that the seat belt legislation was effective for those covered by the law.

B.7 Finland

In July, 1975, Finland mandated belt use for front-seat occupants over the age of 15, but no sanctions were written into the law for noncompliance. In the ten years before the law took effect, belt use increased from 15% to 20%. Restraint use was observed immediately before and immediately after the effective date of the new law, as well as one year later. Weekday belt use among highway motorists was 30% before the law, 68% after, and 64% one year later. Sunday use among highway motorists went from

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6. Technical effectiveness estimate was based on detailed analyses by Griffiths and others, 1976.

7. The crash likelihood (and therefore injuries from such crashes) from November through January when the pre-law measurements were taken is likely to vary from that in February through April, the post-law measurement period.

40% before to 71% after and 67% one year later. Restraint use among urban motorists increased from 9% before to 53% immediately after the law, but decayed to 37% one year later (Oranen, 1977).

An observational survey performed in 1978 (Oranen and Koivurova, 1981) found that when belts were available, usage rates were 71% on highways and 41% in urban areas. Fisher (1980), citing Berard-Andersen, reported that belt use before the Finland law was 8% in urban areas and 31% in rural areas. The corresponding post-law figures were 38% and 66%.

Starting in April, 1982 the seat belt law in Finland was amended such that non-compliance became punishable by a fine or imprisonment. Usage promptly increased to 87% in urban areas and 86% in rural areas. The law was changed again in September, 1983 and the enforcement provision allowed for an immediate on-the-spot fine for those caught not wearing a belt. When the immediate fine provision was implemented use remained essentially the same (82% in urban areas and 92% in rural areas; Marburger, 1986).

B.8 France

France has required belt use since July, 1973, for motorists traveling on rural roads and highways. In January, 1975, the law was extended to urban highways and all urban roads at night; and in October, 1979, the law was again extended to include all roads and times of day. This gradual implementation was additionally complicated by phasing in different model years and vehicle types (vans, light commercial vehicles) at various points during the six year period (Gerondeau, 1979; Hedlund, 1986). Fisher (1980) reported belt use of 20-25% before the 1973 law and 80% after during July, 1973, falling to 50% in October, 1973. Chodkiewicz and Dubarry (1977) reported the following belt use data based on "police controls": 20% in 1972, 26% in 1973, 67% in 1974, and 80% in 1975. They also reported a 21% decline in the number of traffic fatalities between 1972 and 1975.

Gerondeau (1979) provided the most complete data on belt use on French highways after the law took effect. One week after the July 1, 1973 implementation of the law, 80% of rural motorists used belts. By November, 1973, however, use dropped to 50%. Strengthened enforcement brought use back up to 80% in early 1974, but it then declined slightly to 70-75% by 1979. In a later report, Gerondeau (1981) reported use figures as follows: 54% in 1974; 76% in 1975; 79% in 1976; 72% in 1977; 67% in 1978; 69% in 1979; and 79% in 1980. The variation in those estimates may result from the sampling design (details of which were not provided). However, the expansion of mandatory belt use to city driving probably resulted in more drivers belting up whenever on the road, since use on highways increased 10% at the time of that legal change.

Hartemann and others (1984) reported on the effects of seat belt legislation in France from 1973 to 1982. The lowering of speed limits in 1973 and again in 1974 made assessment of the immediate effects of the belt law impossible. However, the authors plotted the fatality rate per vehicle in use for eight and a half years after the law. Traffic deaths were steadily declining while exposure as measured by total number of vehicles was increasing yearly. They concluded that the fatality rate had decreased 50% since implementation of the law. Restraint use in 1982 was reportedly 95% on highways and 75% on other roads outside urban centers.

Lassarre (1986) used Box-Jenkins time series modeling to separate effects of the seat belt law from effects of the speed limit reductions introduced in the same year. Data included monthly traffic volume index for the French national roads from the Ministry of Transport, as well as speed measurements and seat belt use rates of front-seat occupants from the same sampling points for the years 1970-1977. The speed limit changes took effect in June and December 1973; the seat belt law became effective July 1, 1973. By including dummy variables indicating the beginning of these safety measures, monthly variations in the number of deaths due to variations in traffic, speed and seat belt use were calculated. Results indicated that the effect of the speed limit changes was largest in the first quarter of 1974 and became weaker in each subsequent year. Effects of increased seat belt use on number of fatalities

increased over time. The estimated number of lives saved due to seat belts went from 92 per month in 1973 to 295 per month in 1975 through 1977.

B.9 Ireland

Ireland mandated restraint use for front-seat occupants effective February, 1979. Hearne (1981) conducted small-scale surveys in the fall of 1978 and the summer of 1979, in an attempt to identify effects of the law. Belt use among drivers on national roads increased from 19% in 1978 to 46% in 1979, while passenger use increased from 17% to 52%. Belt use for drivers traveling on other types of roads were 9 to 38% for drivers, and 12 to 48% for passengers. Motor vehicle crash data for February to December, 1979 were compared with similar data for 1977 and 1978. Results showed the number of drivers killed or seriously injured in multiple car collisions declined 4%, while the number of drivers killed in single car collisions increased. Based on these figures Hearne concluded that the effect of the law "was minimal."

McCarthy and others (1984) analyzed the effect of Ireland's seat belt law using vehicle miles traveled as a control. Results indicated a reduction of 7% in fatalities per mile driven as a result of the law. Hedlund (1986) also analyzed the data for the first eleven months of Ireland's seat belt law. He reported that the casualty rate was unchanged after the law because as injury and fatality rates for belted occupants decreased slightly, the rate for the unbelted population increased. Due to reporting problems and the small number of cases (570 deaths in three years) a precise assessment was impossible. Nevertheless, the author reports an apparent 2% increase in passenger fatalities following the law.

B.10 Israel

In July, 1975, Israel mandated restraint use for front-seat occupants 14 years of age and older traveling on nonurban roads. Hakkert and others, (1981) observed belt use on three main roads and at three gasoline stations. Belt use on the main roads increased from 6% before to 77% immediately after the law was passed. Use increased to 83% in 1976, but declined to 70% in 1977. They also examined fatality and injury data for urban and nonurban roads for a thirty-month period after implementation of the belt law. Using urban roads for comparison, net effects associated with the law were a 42% decline in driver fatalities, and a 44% decline in passenger fatalities. Interpretation of the casualty reductions is complicated by fuel shortages and reduced speed limits occurring during the same period.

Hedlund (1986) obtained similar results using these data. With urban fatalities as a control, the overall fatality reduction was 41% for the first thirty months of the law. The author cautions, however, that these estimates are quite uncertain because of the small fatality counts (220 deaths in four years).

B.11 Luxembourg

Luxembourg made belt use compulsory among drivers and front-seat passengers beginning June, 1975. Fisher (1980) noted that some officials indicated that the frequency of fatalities and the severity of injuries declined after the belt law; reports of research substantiating such claims are not available.

B.12 Netherlands

The Netherlands implemented a mandatory belt law for drivers and front-seat passengers in June, 1975. Fisher (1980) reports that use went from 11% to 58% in urban areas and from 24% to 75% in rural areas after the law took effect. In 1983 use in urban areas was 46% and in rural areas 65% (Vaaje, 1986).

B.13 New Zealand

New Zealand implemented compulsory belt use in June, 1972. Belt use in May, 1972, immediately before the new law took effect, was 40% (Toomath, 1977). In June, 1972, use jumped to 87%, declining slightly to 83% in 1974, but increasing to 89% in 1975. Assuming that the small changes in estimated use between 1972 and 1975 resulted from sampling error, it appears that New Zealand's belt law resulted in an immediate and sustained increase in restraint use. A decreased effect of the law after a year or more, as seen in several other jurisdictions, apparently did not occur in New Zealand. Toomath also examined occupant fatalities and found a 3% increase from the two-year period immediately preceding the belt law to the two-year period immediately following. This 3% increase in occupant fatalities was in contrast to a significant ($p \leq 0.05$) increase in other road user fatalities (i.e., motorcyclists, pedestrians) of almost 40%, and an increase in gasoline sales of over 12%. The small increase in fatalities among motor vehicle occupants covered by the belt law, during a period in which exposure to crash risk increased and other traffic fatalities increased substantially, provides evidence that the belt law prevented fatalities.

Hedlund (1986) also examined the data for the first two years following implementation of New Zealand's seat belt law. He pointed out that about 60% of the increase in other road user fatalities was attributable to motorcycles, and was concurrent with a 50% increase in motorcycle registrations during that two year period. Occupant casualties in post-1965 vehicles (all of which had belts) were analyzed using pre-1965 vehicles for comparison (pre-1965 vehicles were exempt from the law and in most cases were not equipped with belts). The results indicated a 43% reduction in casualties for those covered by the law.

B.14 Norway

Norway implemented a mandatory belt law for drivers and front-seat passengers in September, 1975; however, no penalties were assessed for noncompliance. In 1976, use in urban areas increased from about 15% before the law to 28% immediately after, and 30% in 1977. The corresponding figures for rural areas were from 37% to 60% (Fisher, 1980). Beginning October 1, 1979 a fine was imposed for noncompliance and enforcement commenced; seat belt use in March, 1980 was reportedly 74% in urban areas and 90% in rural areas (Oranen and Koivurova, 1980). The Nordic Traffic Safety Council (1984) compared traffic crash data from 1978 and 1980 and observed a 10% decline in fatalities among front-seat car occupants. However, other road user fatalities (excluding car occupants), declined by 22%. McCarthy and others (1984) analyzed the Norwegian belt law using annual vehicle miles traveled as a control, and reported a 21% reduction in rate of fatalities per mile driven after implementation of the law. Hedlund (1986) compared fatality rates for the year prior to the imposition of fines to the following year and found a 29% fatality reduction with the model using no controls. However, when other road user fatalities were used for comparison, front-seat occupant deaths increased after enforcement of the law began. It should be noted that these analyses were based on only 352 occupant fatalities in the two years studied.

B.15 Puerto Rico

Occupant restraint use has been mandatory for motor vehicle drivers and passengers in Puerto Rico since January, 1974. Fisher (1980) reported an increase in belt use from 5% in July, 1973, to 24% in May, 1974. Belt use fluctuated during the subsequent years, varying between a low of 7% in September, 1974 and a high of 34% in January, 1976. The most recent reported use rate was 14% in May, 1977. There was some evidence that traffic fatalities were negatively associated with belt use rates, but details were not provided.

B.16 South Africa

South Africa began mandating the use of seat belts by front-seat occupants in December, 1977. Fernie (1980) reported belt use was 18% a month before the law took effect, and jumped to 62% by March, 1978, and 70% by September, 1979. Fernie also conducted preliminary analyses of the effects of the law on traffic injuries and fatalities. Passenger cars (subject to the new law) were compared to light commercial vehicles (not subject to the new law) both before and after December, 1977. No significant change in fatality rates was found to be associated with the belt law. Fernie notes that major confounding factors, such as a motor fuel shortage and significantly increased fuel prices in 1979, complicate interpretation of the results. McCarthy and others (1984) analyzed South Africa's belt law using vehicle miles traveled as a control, and reported an 8% decline in the rate of fatalities per mile traveled associated with the law.

B.17 Sweden

Sweden began mandating restraint use in January, 1975, for front-seat occupants over 14 years old. Bohlin (1979) reported an increase in belt use among front-seat occupants from 35% in 1974 to 84% in 1975. During the first year with the new law, fatalities among motor vehicle occupants decreased 12% and serious injuries decreased 20%. Bohlin estimates cost savings resulting from the legislation of about $33 million U.S. dollars in 1975 alone. Additional follow-up data are reported by Fisher (1980), based on a report by Tingvall. These more recent data show that belt use rates were 36% in 1974, prior to the law, increased to 79% in 1978 in urban areas and to 87% in rural areas.

Most recently Norin and others (1984) reported 80% restraint use in Sweden in 1983. These researchers also reported that in 1975 there were 12% fewer fatalities than expected levels based on motor fuel consumption. Hedlund (1986) reviewed Norin's study and commented that using fuel consumption as a control may overestimate fatality reductions, since fatality rates per fuel consumed are declining generally. However, McCarthy and others (1984) reported results similar to Norin's using a model which controlled for exposure based on vehicle miles driven. McCarthy found a 14% reduction in fatalities per miles driven following implementation of the seat belt law.

B.18 Switzerland

A mandatory seat belt law was implemented in Switzerland in January, 1976. Public opposition to the law was evident soon after it took effect, and the law was challenged in court. In the fall of 1977, the Supreme Court ruled in two separate cases that the mandatory belt law was invalid, which had the effect of repealing the law. A new law was reinstated by the government on July 7, 1981. Swiss government reports summarized by Fisher (1980) indicate that belt use increased from about 35% before to over 90% immediately after implementation of the law, but began to decline after several months. The downward trend continued through 1978. Use figures for September, 1978 (almost a year after the law was repealed) were 64% on expressways, 46% on rural roads, and 33% on urban streets. Andreasson (1983) has reported more recent use figures, after the belt law was reinstated July 1, 1981. Belt use in 1982 was up to 77% on expressways, 76% on rural roads, and 62% on urban streets.

Fisher also described a study in which occupant fatalities among crash victims were compared for the years 1972, 1973, 1975, and 1976. A 12% decrease in fatalities occurred from 1975 to 1976, while the number of crash involved occupants increased by 16% during this period. This study was conducted solely in the city of Basel, and the results should not be generalized to the nation as a whole. McCarthy and others (1984) examined the data for the year before and year after the belt law in Switzerland. They used vehicle miles traveled to control for exposure. Results indicated a 10% decline in fatalities per mile driven in the first year the law was in effect. Hedlund (1986) compared the year before and year after reinstatement of the law. A simple month to month comparison showed a 15% decrease in fatalities in the first year of the reinstated law. Burris (1986) compared crash reports from police records for the years 1981 and 1982. He concluded that 101 drivers' lives were saved due to the law, assuming that the 1981

death rate for unbelted drivers would have applied to the 20% who started wearing belts after passage of the law, if they had not adopted seat belts.

B.19 West Germany

Occupant restraint use was made mandatory for drivers and front-seat passengers in West Germany beginning January, 1976. Although no fines for noncompliance were established, some courts have viewed lack of belt use as contributory fault in motor vehicle crash cases. Data collected by the Federal Institute for Streets (reported by Fisher, 1980) indicated that belt use increased after the law was implemented, despite the lack of penalties for noncompliance (a finding also reported by Seidenstecher, 1979). Use on all types of roads averaged 28% in August, 1975, 32% in November, 1975, 50% in January, 1976, 46% in March, 1977, 48% in September, 1977,and 58% in September, 1978.

McCarthy and others (1984) analyzed the effect of the West German seat belt law on fatalities using vehicle miles traveled as a control. Results indicated a 4% decline in fatalities per mile traveled during the post-law period (the length of which was not reported).

Beginning in August, 1984 a fine was introduced in West Germany for failure to use seat belts. According to Marburger (1986) seat belt use increased from 58% to 92% in September, 1984. In March, 1986 restraint use was 94%. Hedlund (1986) reported a simple month to month comparison of the crash data for January through June, 1984 with the same period in 1985. Results indicated that car occupant fatalities in the first half of 1985 decreased 25%.

B.20 United States

As of February, 1987 twenty-four states and the District of Columbia, representing 70% of the U.S. population, have enacted mandatory seat belt laws (Stepanek, 1987). This does not include Nevada, whose law is only effective contingent upon Nevada being authorized a 70 mile per hour speed limit; nor Nebraska and Massachusetts where the laws were repealed by referendum in November, 1986. The pattern of seat belt use in the states with belt laws was a typical baseline use rate of 15 to 20%, followed by an initial surge to 50 to 70% in belt use at the time penalties were introduced. Typically, gradual declines were seen beginning in the fourth month after the laws were implemented to 38 to 46%. Texas was an exception, where use rates increased from 55% in the first month with the law to 63% after five months. Strong primary law enforcement efforts by state troopers resulted in 28,000 citations for seat belt violations issued in the first four months with the law, undoubtedly encouraging increased compliance (Williams and others, 1986b).

In March, 1983, the State of **New York** began requiring all drivers with learning permits to use seat belts. Shapiro and others (1984) compared rates of restraint use by learner's permit holders to that of licensed drivers at two local Department of Motor Vehicle (DMV) offices and at a gas station. Learner's permit holders were identified as such at the gas station when they redeemed a coupon for free gas mailed to learner's permit holders under 21 years old in the local DMV jurisdiction. Thirty-nine percent of the learner's permit drivers and 7% of other drivers sampled at the gas station were belted. At the Albany DMV office, observed rates were 32% for permit holders and 12% for other drivers. Belt use for both groups was 6% at the Bay Shore DMV office. Although these comparisons seem to indicate that the regulation had a positive effect, restraint use increased to only 25%. This rate may also be an overestimate, since two-thirds of the observations were made in settings where those with learner's permits are likely to be more compliant (i.e., DMV offices). Methodological inadequacies such as no pre-regulation measures, biased sampling techniques, and small sample sizes preclude any definitive interpretation of these results.

Beginning in September, 1984 all drivers in New York with probationary licenses were required to buckle up, and as of December, 1984 all drivers, front-seat passengers, and children under the age of ten regardless of seating position were required to use seat belts or child restraint devices (Rood and Kraichy,

1985). New York's law is considered to be one of the strongest mandatory use laws passed to date since it carries fines of up to fifty dollars and permits primary enforcement, which began January 1, 1985 after a one month warning period.

Observational studies of seat belt use rates were conducted in New York during the first year of the law. Statewide pre-law belt use was reported at 16%. Due to weather conditions during January, the first month of enforcement, observations were made in only four areas (instead of the usual sixteen). The use rates at that time ranged between 63-75%. In April, 1985 statewide belt use by front-seat occupants was 57%; belt use continued to decline to 46% in September, 1985 (Rood and Kraichy, 1985). Belt use by front-seat occupants in New York was 44% in January, 1986 (Williams and others, 1986).

Lund and others (1986a) measured the effects of the New York law for the first nine months of 1985. Regression analyses were performed using the fatality data from New York as the dependent variable and monthly fatalities in Pennsylvania and Ohio as predictor variables. Monthly fatality counts of vehicle occupant deaths for the period January, 1980 to September, 1985 were used to control for historical trends; only vehicles covered by the New York law were included. Results showed a significant ($p \leq 0.05$) reduction in fatalities of "approximately nine percent."

Pace and others (1986) examined both a three month pre-law (October through December, 1984) and the first five months post-law (January through May, 1985) period following the effective date of the New York seat belt law. Overall seat belt use increased from 23% pre-law to 39% post-law use ($p \leq 0.05$). Seat belt use by drivers jumped from 21% pre-legislation to 47% post-legislation ($p \leq 0.01$) while belt use by front-seat passengers use rose from 21% to 40% ($p \leq 0.20$). Pace also reports that during the first 3 months post-legislation, a 27% decline in motor vehicle related deaths was observed statewide in New York.

Hedlund (1986) analyzed fatalities in New York for the first nine months of the state's seat belt law. Preliminary fatality data for the first nine months of the law were compared to the same period of the previous year and the 1980-1984 average for these months in New York as well as for the same months in the rest of the United States. Calculations were based on a 57% average belt wearing rate in New York during these months. The author reports a 15% fatality reduction as a "conservative preliminary estimate" of the law's effects.

Latimer and Lave (1987) used Poisson and least squares modeling methods to analyze the effects of the New York law during its first six months. Crash-related injury data as reported by the Department of Motor Vehicles were obtained for the period January, 1980 to June, 1985. Results using least squares regression indicate a 24% fatality reduction, while the Poisson method yielded an estimated 20% drop in fatalities during the first six months of the law.

The seat belt law in **New Jersey** became effective on March 1, 1985. According to surveys reported by Lund and others (1986b) the pre-law usage rate was 16-18%. Restraint use increased to 51% in the first month of the law, and eroded thereafter. Belt use by front-seat occupants was 40% four months after the law took effect and 44% in the fifth month of the law. Observations conducted in April, 1986 found 38% of front-seat occupants restrained.

Michigan's mandatory seat belt law took effect on July 1, 1985. A series of observational surveys have been conducted at approximately four month intervals since December, 1984. The first survey wave found a pre-law rate of 18.3% restraint use by adult front-seat occupants. By April, 1985, after passage but before implementation of the law, the rate increased to 24.7%. As has been seen in other jurisdictions, the first month following enforcement brought a dramatic increase in seat belt use, to 60.5%. Use then declined to 44% five months later. Subsequent survey waves indicate that restraint use in Michigan has stabilized. The surveys conducted in April, July, and December, 1986 reported front-seat belt use rates consistently within the narrow range of 44.3-47% (Wagenaar and others, 1987a).

Wagenaar and others (1987b) analyzed the preliminary effects of Michigan's mandatory seat belt law. Time-series analyses were performed using Fatal Accident Reporting System data for the pre-law period January, 1978 through June, 1985, and for the first post-law year, July, 1985 through June, 1986. The results indicated a 10% overall decline in front-seat fatalities. Significant ($p \leq 0.05$) declines of 30% in fatalities per crashed vehicle for front-seat occupants age 10 and over, and 12% in the number of injured occupants age 16 and over. Since both the number of crashes and total miles traveled in Michigan increased during this period, the authors concluded that the seat belt law has been effective in reducing crash-related injuries and fatalities.

Illinois also implemented a seat belt law on July 1, 1985. Mortimer (1986) reported a pre-law belt use rate of 16% in April, 1985. In July 40% of drivers and 38% of front-seat passengers were using seat belts. Belt use increased to 47% August when enforcement officially began (Williams and others, 1986). Seat belt use decreased to 30% by December, 1985 and remained at that level through the most recent survey in August, 1986 according to Mortimer. Mortimer also reported a simple month-to-month comparison of the pre-law period of July, 1984 through March 1985 with the first nine post-law months. Nonoccupant fatalities were used for comparison. A 3% fatality reduction in Illinois was associated with the seat belt law.

Lund and others (1986b) analyzed the effects of mandatory seat belt laws in the four states which had belt laws in effect for at least six months of 1985 (**New York, New Jersey, Michigan, Illinois**). Eight states without seat belt laws were used as comparisons. Time-series analyses identified fatality reductions of 5% in New York, 4% in New Jersey, 4% in Michigan, and 7% in Illinois. Only the New York result was statistically significant ($p \leq 0.01$), and the authors concluded that "substantial reductions in motor vehicle occupant deaths" will not be realized until much higher use rates are attained.

In **Texas** a mandatory belt use law went into effect without sanctions on September 1, 1985. The Texas law provided for fines of $25 to $50 and primary enforcement by law officers beginning December 1, 1985. According to Bunch and others (1986), the pre-law use rate for drivers in Texas was 15%. Although no specific figures are cited, the authors reported a substantial initial increase in use rates concomitant with implementation of the law, followed by slight declines during the three-month warning period. An additional increase in use to 67% was observed when enforcement with sanctions commenced, and belt use continued at "an extremely high level" during the remaining six months of the study. This is confirmed by the Texas Department of Highways and Transportation, which reported seat belt use in Texas was 75% in March, 1986 (Campbell and others, 1986).

Nebraska had a seat belt law in effect from September, 1985 until November, 1986 when it was repealed by voter referendum. A study by the Nebraska Office of Highway Safety reported a pre-law belt use rate of 26% in August, 1985. Restraint use increased to 44% in November, 1985, but had dropped to 38% by February, 1986 (Campbell and others, 1986). Belt use was 40% in October, 1986 the month before repeal of the law. During the most recent survey in February, 1987 belt use had dropped to 29%; furthermore, although the state still requires that children be belted, child restraint use dropped 20 percentage points to 42% after repeal of the seat belt law (IIHS, 1987b).

Missouri's mandatory seat belt law took effect on September 28, 1985. However, the secondary enforcement provision is not scheduled to become effective until July 1, 1987. According to surveys cited by Campbell and others (1986), pre-law restraint use was 12% in July 1985, increasing to only 19% in October, the first month of the law.

As in Missouri, the seat belt law in **North Carolina** also provided for a long warning-only period. Although the law was implemented on October 1, 1985, it was not enforced until January 1, 1987. Restraint use was observed at 25% the month prior to implementation of the law. Post-law surveys done at two month intervals during the first eight months of the law found restraint use consistently within a range of 42% to 48% (Campbell and others, 1986). In January and February 1987, the first two months of enforcement, seat belt use had increased to 78% (IIHS, 1987a).

Preliminary analyses of the effectiveness of the seat belt laws in the first eight states with such laws was done by Campbell and others (1986) (**New York, New Jersey, Illinois, Michigan, Nebraska, Texas, North Carolina, Missouri**). Fatal Accident Reporting System data for the years 1975-1985 were analyzed, using time-series analyses, simple month-to-month pre-to-post law comparisons, and comparisons between front-seat occupants, rear-seat occupants, and nonoccupants. Results of the time-series and month-to-month comparisons indicated a distinct downward shift in front-seat occupant deaths at the time the laws took effect. Time-series analyses estimated a 9.9% decrease in fatalities to occupants covered by the laws. The results were significant in four of the eight states, with the most significant ($p \leq 0.01$) reduction seen in Texas, which had 17.6% fewer fatalities than would have been expected without the law.

Hoxie and Skinner (1987) analyzed the effects of mandatory seat belt laws in the eighteen U.S. jurisdictions which had laws in force prior to June 30, 1986. In addition to the eight states already mentioned, **Hawaii, California, Connecticut, Massachusetts, New Mexico, Tennessee, Utah, Ohio, Washington, and the District of Columbia** were included in this study. Fatal Accident Reporting System data were obtained for the period January, 1975 through June, 1986. Two models were used, the first compared fatalities in the belt-law states to the rest of the nation, the second examined the seven largest states with belt laws in effect for more than six months of the study period (Illinois, Michigan, Missouri, New Jersey, New York, North Carolina, Texas). Regression models were used to estimate fatality reductions. Fatalities per capita in each state were divided into front-seat vehicle occupants and all others (including other vehicle occupants, pedestrian, bicycle, motorcycle, and heavy truck fatalities). The national model indicated an average reduction of 5.8% in front-seat occupant fatalities attributable to the seat belt laws. The effect was greatest during the first quarter of the laws, where a significant ($p \leq 0.05$) reduction of 9% in front-seat occupant fatalities was found. The state model found front-seat occupant fatality reductions in six of the seven states; the results were statistically significant in Michigan ($p \leq 0.10$) and Texas ($p \leq 0.05$). The first quarter effect was also seen in the individual states, with significant ($p \leq 0.05$) fatality reductions of 22% in Michigan and 18% in Texas; three of the other states had reductions over 10%. These results are interesting in that Texas, where the law has been rigorously enforced, was the only state where the effect of the seat belt law did not diminish with time. Missouri, where the law has not been enforced to date, actually experienced an increase in fatalities.

Partyka (1987) evaluated the effect of seat belt laws in **New York, New Jersey, Illinois, Michigan, Texas, Nebraska, Missouri, and North Carolina**. Using crash data for the years 1983, 1984, and 1985, front-seat occupant fatality rates were compared to other occupant and nonoccupant fatalities in the law states and to front-seat occupant fatalities in the non-law states. Results indicated a 7% fatality decline in 1985 attributable to the seat belt laws.

In addition to the states noted above, **Louisiana, Maryland, Idaho, Kansas, Iowa, Minnesota, Florida, and Oklahoma** have implemented adult mandatory restraint laws; a law in **Indiana** is scheduled to take effect on July 1, 1987.