ALASKA LEGISLATURE COMMITTEE FILES 1981-1982 8672

1327 HHESS HB 112

Table 4.1 ARIMA Model Estimation Results for the Frequency of Three-factor-surrogate Crash Involvement Among 18 - 20 Year Old Drivers in Michigan

ESTIMATION SUMMARY — TERMINATION:SSQ CONVERGENCE

DIFFERENCING: 0
SEASONAL DIFFERENCING: 0
SEASONAL SPAN: 12
TRANSFORMATIONS: NONE

VARIABLE: 9
LABEL:F3S18.C
CASES: 1- 84
ADJUSTED SSQ.0.25763E+05

PARAMETER NUMBER	PARAMETER TYPE	ORDER	BEGINNING VALUE	ESTIMATED VALUE	95 PER CENT LOWER LIMIT	95 PER CENT UPPER LIMIT
1	DELTA		0.10000E+03	0.25440E+02	0.85864E+01	0.42295E+02
2	AR	1	0.57000E+00	0.50347E+00	0.29043E+00	0.71651E+00
3	ARS	1	0.58000E+00	0.64463E+00	0.43596E+00	0.85330E+00

RESIDUAL AUTOCORRELATIONS:	CASES	DF	Q	SIG
	1- 84	17	0.10281E+02	.8914

1- 10	-0.05	0.14	-0.03	-0.16	0.13	0.03	-0.04	-0.04	-0.12	-0.04
ST.E.	0.11	0.11	0.11	0.11	0.11	0.12	0.12	0.12	0.12	0.12
11- 20	0.03	-0.06	0.09	-0.07	-0.01	-0.02	-0.11	0.11	-0.05	0.01
ST.E.	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12

PARAMETER CORRELATION MATRIX

	1	2	3
1	1.0000		
2	-0.4922	1.0000	
3	-0.7507	-0.1776	1.0000

between the parameters may be an indication of redundancy in the model that could be reduced by simplifications in the specified model. One consequence of high parameter correlations, according to McCleary and Hay (1980:303), is that the sum of squares function

> . . . may not have one clearly defined minimum, but rather several minima, each associated with a particular configuration of the redundant parameters. When the (non-linear estimation) algorithm attempts to solve a function of this sort, it may oscillate between several minima without ever converging.

Although the correlation between the seasonal auto-regressive and the constant terms was relatively high (-.76), the decision was made to retain the constant term in the preliminary noise model and reassess the need for the constant term when the combined ARIMA/transfer function model was evaluated.

For several of the variables examined in the present study, an examination of the autocorrelations and partial autocorrelations for the appropriately transformed and differenced data revealed that more than one model could plausibly be specified to account for the observed pattern of serial correlations. In such cases maximum likelihood parameter estimates were obtained for each plausible model. Each model was assessed using the criteria discussed above and any modified models that appeared necessary were also evaluated. If more than one resulting ARIMA model met all of the evaluative criteria, the model with the lowest sum of squares was selected to represent the baseline series.

The second major stage of the Box-Jenkins intervention analysis strategy is the identification, estimation, and evaluation of a transfer function model to describe the nature of the intervention impact on the

criterion variable. The form of the initial transfer functions for each of the accident series was selected on the basis of the hypothesized intervention effects. The major exogenous factor of interest, the raised legal drinking age, was represented by an abrupt, permanent impact pattern transfer function model.

A second major exogenous factor influencing the frequency of motor vehicle crashes between 1972 and 1979 was the fuel shortage and maximum legal speed limit reduction of early 1974. To reduce the residual error variance and more accurately assess the impact of the raised drinking age, a first-order dynamic transfer function was included to account for the changes in crash frequency associated with the events of early 1974.

In summary, the complete model included: (A) a transfer function for the determination of the raised drinking age impact, (B) a dynamic transfer function controlling for the effects of the fuel shortage/speed limit reduction of 1974, and (C) a parsimonious ARIMA model controlling for trends, seasonality, and other autocorrelation components in the criterion time-series. The parameters of this combined model were simultaneously estimated.

The estimation results are presented in Table 4.2. Since the estimate of the constant term was not significantly different from zero, it was likely that a more parsimonious model, without a constant term, would also adequately account for the pattern of crash frequency over time. The moderately high correlations between the constant and the auto-regressive parameters noted earlier (Table 4.1), indicated that the sum squares function might not have a steep depression but rather a

Table 4.2 Initial Estimation Results for Combined ARIMA/Transfer Function Model of Three-factor-surrogate Crash Frequency Among Drivers Aged 18 - 20

Noise Model: ARIMA (1,0,0)(1,0,0)12 with no transformations
Fuel Shortage Transfer Function: rsb (1,0,0) with pulse function input
Raised Drinking Age Transfer Function: rsb (0,0,0) with step function input

	Parameter Estimates	Standard Errors
Fuel Shortage	ω = -17.27	14.03
	δ = .71	.39
Raised Drinking Age	ω = -29.86	8.34
	ϕ_1 = .34	.11
	Γ_1 = .74	.09
	α = 12.91	13.27

shallow trough. Based on these considerations, the model's parameters were re-estimated without a constant term included. The results, presented in Table 4.3, indicated that the model adequately and parsimoniously accounted for the frequency of 3FS crashes among drivers aged 18-20 over the 1972 through 1979 time period (Figure 4.4). First, the noise model parameters and the auto-regressive parameter in the fuel shortage transfer function met the requirements for system stability. Second, the noise model parameters were significantly different from zero. Third, none of the residual autocorrelations were significantly different from zero (the Q-statistic was 18.01 for lags one through 24; $p>.05$). Fourth, all of the parameter correlations were .37 or less. Finally, the full model accounted for about 67 percent of the variance of the raw time-series. The goodness of fit of the model to the data can be seen in Figure 4.5, where the actual crash frequency and the frequency predicted by the final model are plotted on the same graph.

On the basis of the criteria discussed above, it was clear that an adequate model of the frequency of 3FS crashes among drivers 18-20 had been achieved, and the model could therefore be used to assess the changes in crash frequency associated with raising the legal minimum drinking age. The estimation results indicated that after the drinking age was raised in December of 1978, there was an average reduction of 27.5 crashes per month in the time-series analyzed (Table 4.3); this effect was statistically significant with $p<.01$. The average monthly reduction of 27.5 crashes over the first 12 months after the drinking age was raised represents a 17.74 percent reduction in late-night, single-vehicle, male, 18-20 year old driver crash involvements when compared to the frequency of such crashes

Table 4.3 Final Estimation Results for Combined ARIMA/Transfer Function Model of Three-factor-surrogate Crash Frequency Among Drivers Aged 18 - 20

Noise Model: ARIMA (1,0,0)(1,0,0)12 with no transformations
Fuel Shortage Transfer Function: rsb (1,0,0) with pulse function input
Raised Drinking Age Transfer Furction: rsb (0,0,0) with step function input

	Parameter Estimates	Standard Errors
Fuel Shortage	ω = -16.91	14.10
	δ = .71	.40
Raised Drinking Age	ω = -27.50	8.06
	ϕ_1 = .35	.11
	Γ_1 = .73	.09

Residual Variance = 320 R-sqr = .67 Q = 18.01

Residual Autocorrelations: Approx. standard error = .11

1:-.09	2: .19	3: .00	4:-.17	5: .08
6:-.07	7:-.07	8:-.03	9:-.08	10:-.07
11: .13	12:-.17	13: .07	14:-.05	15:-.06
16:-.03	17:-.13	18:-.04	19:-.03	20:-.07
21:-.01	22:-.09	23: .08	24: .13	

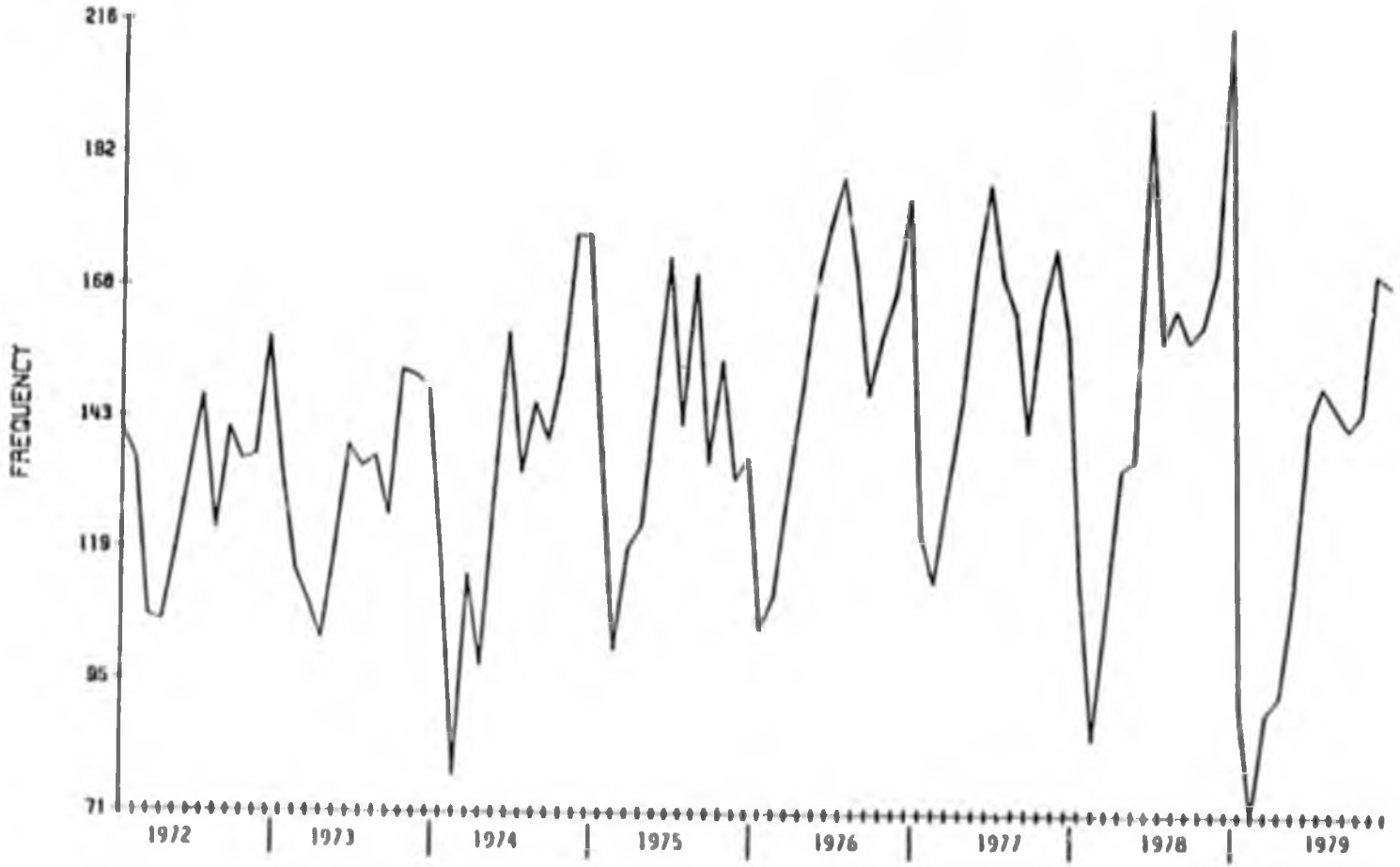

Figure 4.4 Frequency of Three-factor-surrogate Crash Involvement Among 18 - 20 Year Old Drivers in Michigan, 1972 - 1979

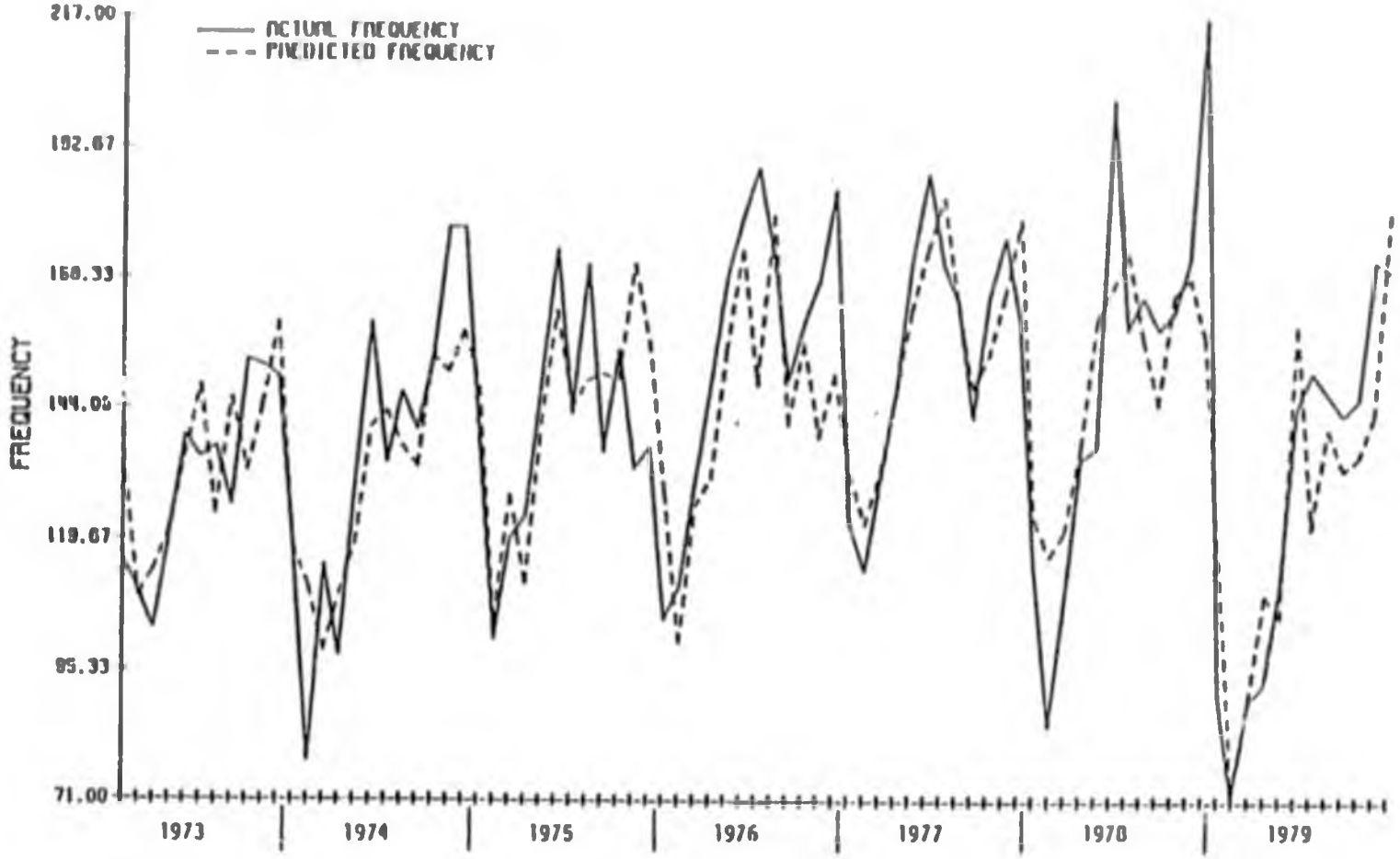

Figure 4.5 Actual and Predicted Frequency of Three-factor-surrogate Crash Involvement Among 18 - 20 Year Old Drivers in Michigan, 1973 - 1979

expected had there been no change in the drinking age. The 17.74 percent reduction in crashes can be interpreted as the net effect associated with the raised drinking age, controlling for the effects of (A) the fuel shortage/speed limit reduction of early 1974, (B) trend and seasonal variation in crash frequency, and (C) random variation in the frequency of motor vehicle crashes.

However, the drinking age transfer function estimate of -27.5 crashes cannot be directly used as a point estimate of the actual number of 3FS crashes prevented by raising the drinking age, since the model was estimated using a time-series based on a random 20 percent sample of all reported crashes. The best point estimate of the actual number of crashes prevented by the legal change is obtained by multiplying the transfer function point estimate (i.e., -27.5) by the inverse of the sampling fraction (i.e., 5), resulting in the estimate of 137.5 crash involvements per month prevented by the legal change. Over the first twelve months after the drinking age was raised, therefore, an estimated 1650 3FS crashes among 18-20 year old drivers were prevented.

Although not the focus of the present investigation, the full model results presented in Table 4.3 also provide information concerning changes in 3FS crashes associated with the fuel shortage/speed limit factors. The results indicated that a statistically non-significant, temporary reduction in 3FS crashes occurred in early 1974. It should be noted, however, that the fuel shortage/speed limit effect estimates based on the analysis of 1972 through 1979 crash frequencies should be interpreted with caution, since the point estimates were based on a short baseline series. As discussed in Chapter 3.0, the main purposes for

including the transfer function for the fuel shortage/speed limit effects in the analyses were: (A) to determine the effects associated with the modifications in the legal drinking age independent of the well established impact of the fuel shortage and speed limit reduction, and (B) to reduce the residual error variance (and consequenctly increase the precision of the drinking age parameter estimates) by accounting for this major exogenous shock to the system causing the crash time-series.

In summary, the iterative specification, estimation, and evaluation strategy of modeling time-series suggested by Box and Jenkins resulted in an ARIMA model that adequately represented the autocorrelation structure of the monthly frequency of 3FS crashes among 18-20 year old drivers. The ARIMA model was combined with two transfer functions, representing the effects of the 1974 fuel shortage/speed limit reduction and the hypothesized effects of raising the legal minimum drinking age. The iterative specificaton, estimation, evaluation process was repeated for the combined ARIMA/transfer function model. The final resulting model revealed a highly significant reduction in 3FS crash frequency associated with raising the drinking age, with a magnitude of approximately 18 percent, or 137.5 crash involvements per month.

4.2 Time-series Models of Michigan Total Crash Frequencies, 1972 - 1979

The iterative model building strategy was applied to each of the time-series included in the full design matrix (see Table 3.1). The estimation results for each of the variables based on the 20 percent random sample file are presented below. Included for each variable are: (A) a plot of the raw series (Figures 4.6 to 4.15), and (B) the final

combined ARIMA/transfer function model estimation results (Tables 4.4 to 4.14). (3) The full complement of diagnostic statistics are included for each model, verifying its appropriateness for estimation of the effect of the raised drinking age.

The first hypothesis of this investigation was that raising the legal minimum drinking age would result in reduced alcohol-related traffic crashes among 18-20 year old drivers. The time-series modeling results, summarized in Table 4.15, revealed highly significant reductions both in police-reported had-been-drinking crashes and three-factor-surrogate alcohol-related crashes among 18-20 year old drivers after the drinking age was raised. Police-reported HBD crashes dropped by 30.72 percent, and 3FS crashes were down by 17.75 percent from what would have been expected had there been no drinking age change. (4)

The main "control" series specific to 18-20 year old drivers was the frequency of police-reported "had not been drinking" crashes. A small reduction in HNBD crashes was evident, but it was not statistically significant and small in magnitude compared to the drop in the frequency of HBD or 3FS crashes (Table 4.15). The observed substantial reductions in HBD and 3FS alcohol-related crash frequencies, and no significant change in HNBD non-alcohol-related crashes, provided strong support for hypothesis one, that is, that the raised legal drinking age caused a reduction in alcohol-related traffic accidents among drivers aged 18-20.

It was also hypothesized that the raised legal drinking age would cause a reduction in alcohol-related crash involvement among drivers aged 16-17. Analyses of 3FS crashes among drivers of this age group revealed a significant reduction associated with the raised legal age

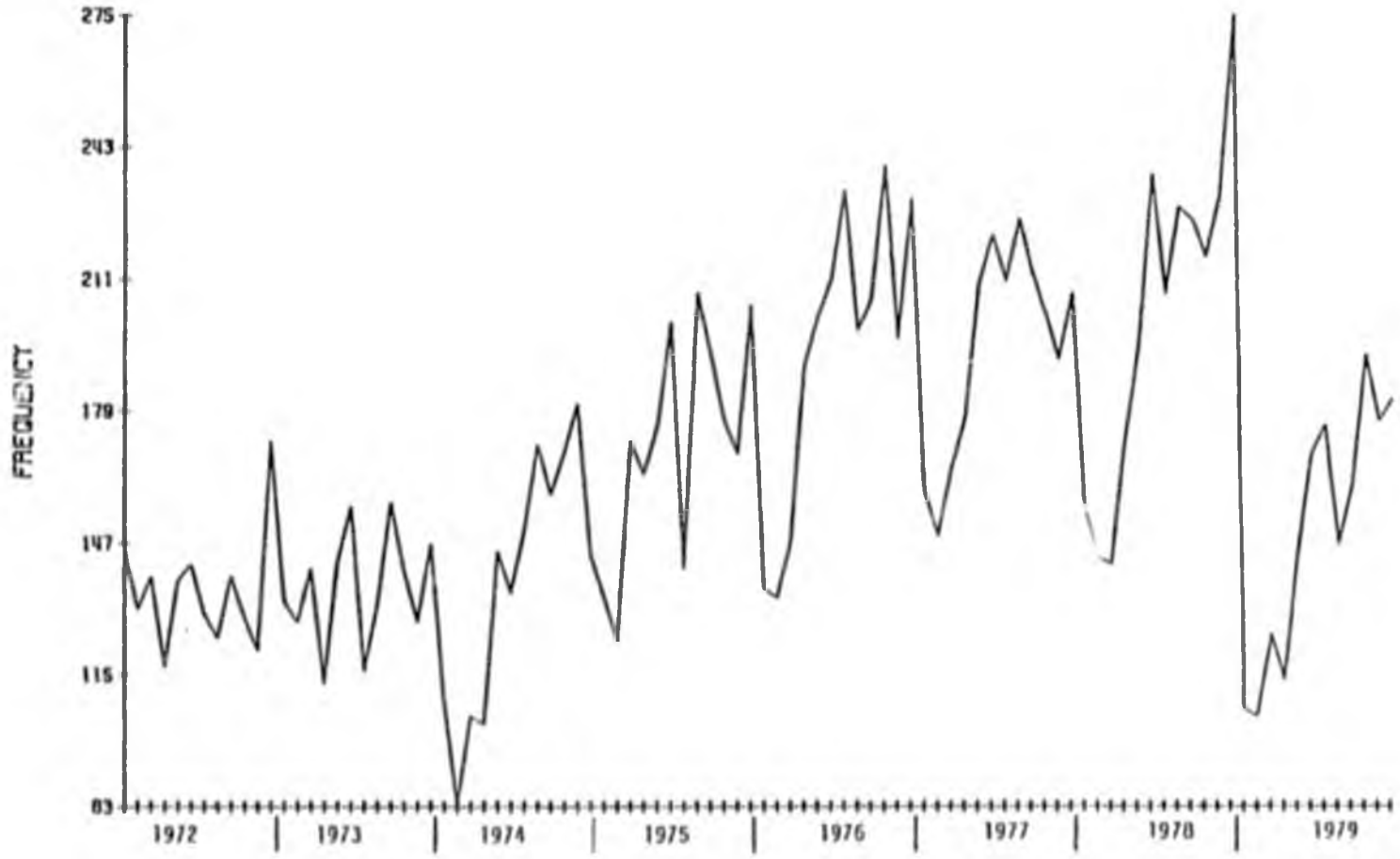

Figure 4.6 Frequency of Had-been-drinking Crash Involvement Among 18 - 20 Year Old Drivers in Michigan, 1972 - 1979

Table 4.4 Final Estimation Results for Combined ARIMA/Transfer Function Model of Had-been-drinking Crash Frequency Among Drivers Aged 18 - 20

Noise Model: ARIMA (3,0,0)(1,0,0)12 with log transformation
Fuel Shortage Transfer Function: rsb (0,0,0) with four month pulse function input
Raised Drinking Age Transfer Function: rsb (0,0,0) with step function input

	Parameter Estimates	Standard Errors
Fuel Shortage	ω = -.293	.055
Raised Drinking Age	ω = -.367	.063
	ϕ_1 = .080	.113
	ϕ_2 = .021	.112
	ϕ_3 = .335	.113
	Γ_1 = .792	.084
	α = .331	.195

Residual Variance = .0165 R-sqr = .77 Q = 27.75

Residual Autocorrelations: Approx. standard error = .11

1:-.04	2: .02	3:-.02	4: .03	5:-.09
6: .02	7: .12	8:-.10	9:-.21	10: .10
11: .10	12:-.19	13: .31	14: .05	15:-.10
16:-.16	17:-.07	18:-.11	19:-.06	20:-.05
21: .07	22:-.19	23: .07	24: .07	

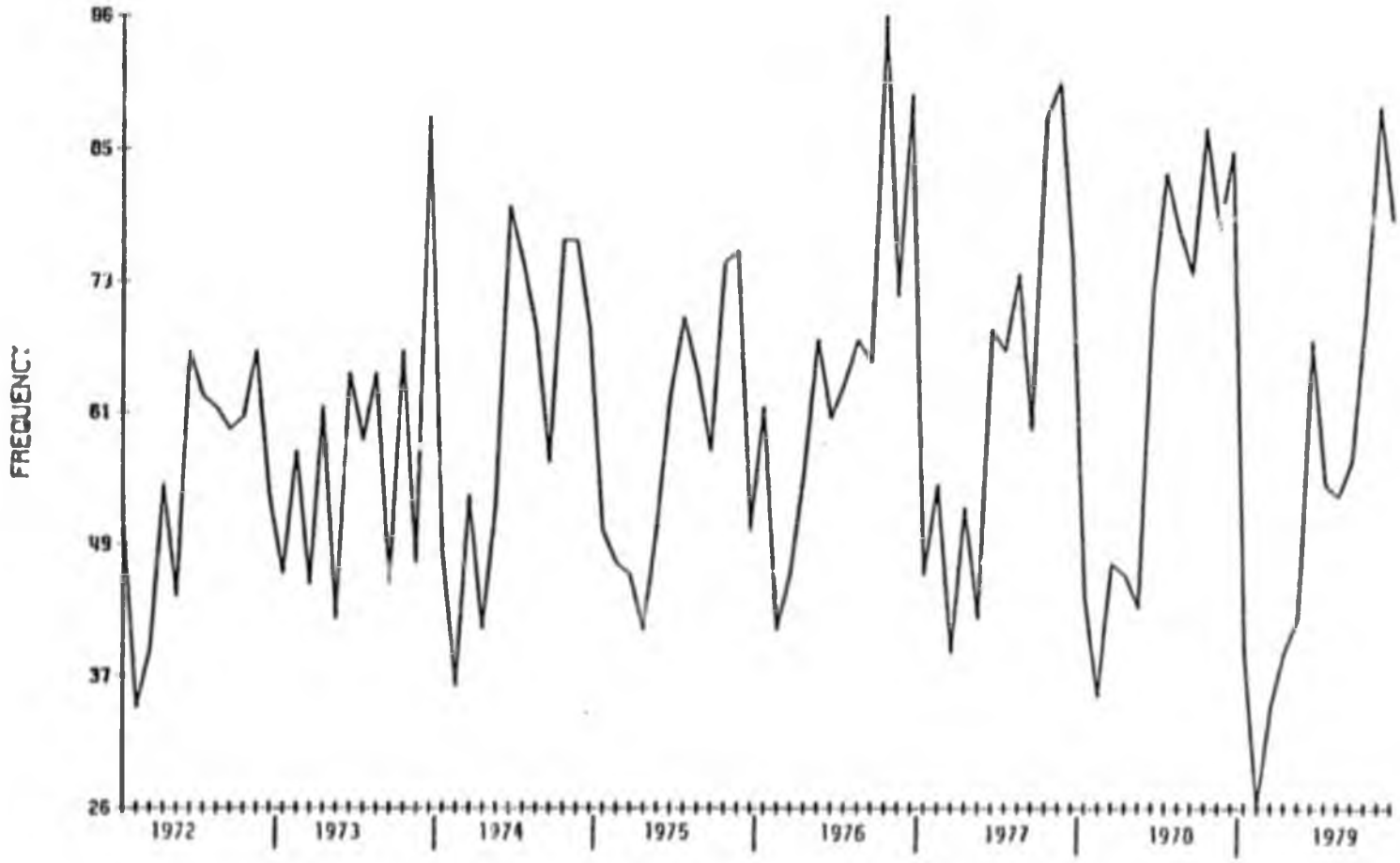

Figure 4.7 Frequency of Three-factor-surrogate Crash Involvement Among 16 - 17 Year Old Drivers in Michigan, 1972 - 1979

Table 4.5 Final Estimation Results for Combined ARIMA/Transfer Function Model of Three-factor-surrogate Crash Frequency Among Drivers Aged 16 - 17

Noise Model: ARIMA (0,0,0)(1,1,0)12 with no transformations
Raised Drinking Age Transfer Function: rsb (0,0,0) with step function input

	Parameter Estimates	Standard Errors
Raised Drinking Age	ω = -9.45	3.05
	Γ_1 = -.50	.10

Residual Variance = 112 R-sqr = .65 Q = 20.26

Residual Autocorrelations: Approx. standard error = .11

1:-.11	2: .10	3:-.16	4: .04	5:-.24
6: .05	7:-.15	8: .11	9:-.02	10:-.04
11: .13	12:-.11	13:-.04	14:-.06	15: .09
16:-.17	17: .07	18:-.02	19: .09	20:-.10
21: .00	22: .07	23: .09	24:-.16	

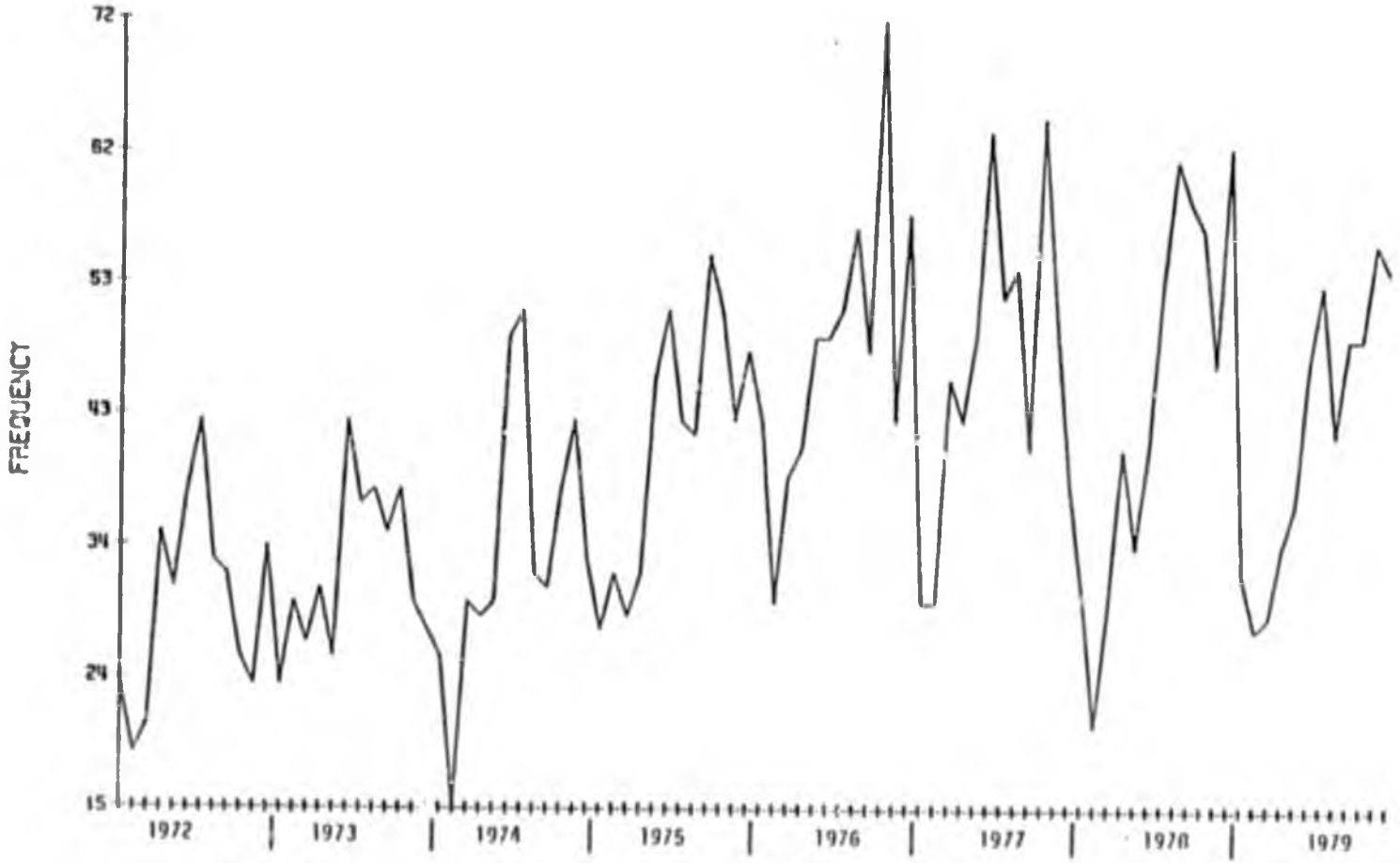

Figure 4.8 Frequency of Had-been-drinking Crash Involvement Among 16 - 17 Year Old Drivers in Michigan, 1972 - 1979

Table 4.6 Final Estimation Results for Combined ARIMA/Transfer Function Model of Reported Had-been-drinking Crash Frequency Among Drivers Aged 16 - 17

Noise Model: ARIMA (1,0,0)(1,0,0)12 with no transformations
Fuel Shortage Transfer Function: rsb (1,0,0) with pulse function input
Raised Drinking Age Transfer Function: rsb (0,0,0) with step function input

	Parameter Estimates	Standard Errors
Fuel Shortage	ω = - 7.88	5.10
	δ = .90	.13
Raised Drinking Age	ω = - 3.40	3.36
	ϕ_1 = .19	.12
	Γ_1 = .54	.10
	α = 4.56	2.82

Residual Variance = 75 R-sqr = .57 Q = 22.38

Residual Autocorrelations: Approx. standard error = .11

1:-.01	2: .05	3: .04	4: .05	5:-.02
6:-.17	7:-.02	8:-.09	9:-.15	10: .15
11: .15	12:-.17	13: .15	14: .10	15: .06
16:-.12	17:-.06	18: .04	19:-.22	20:-.09
21:-.03	22:-.01	23:-.04	24: .10	

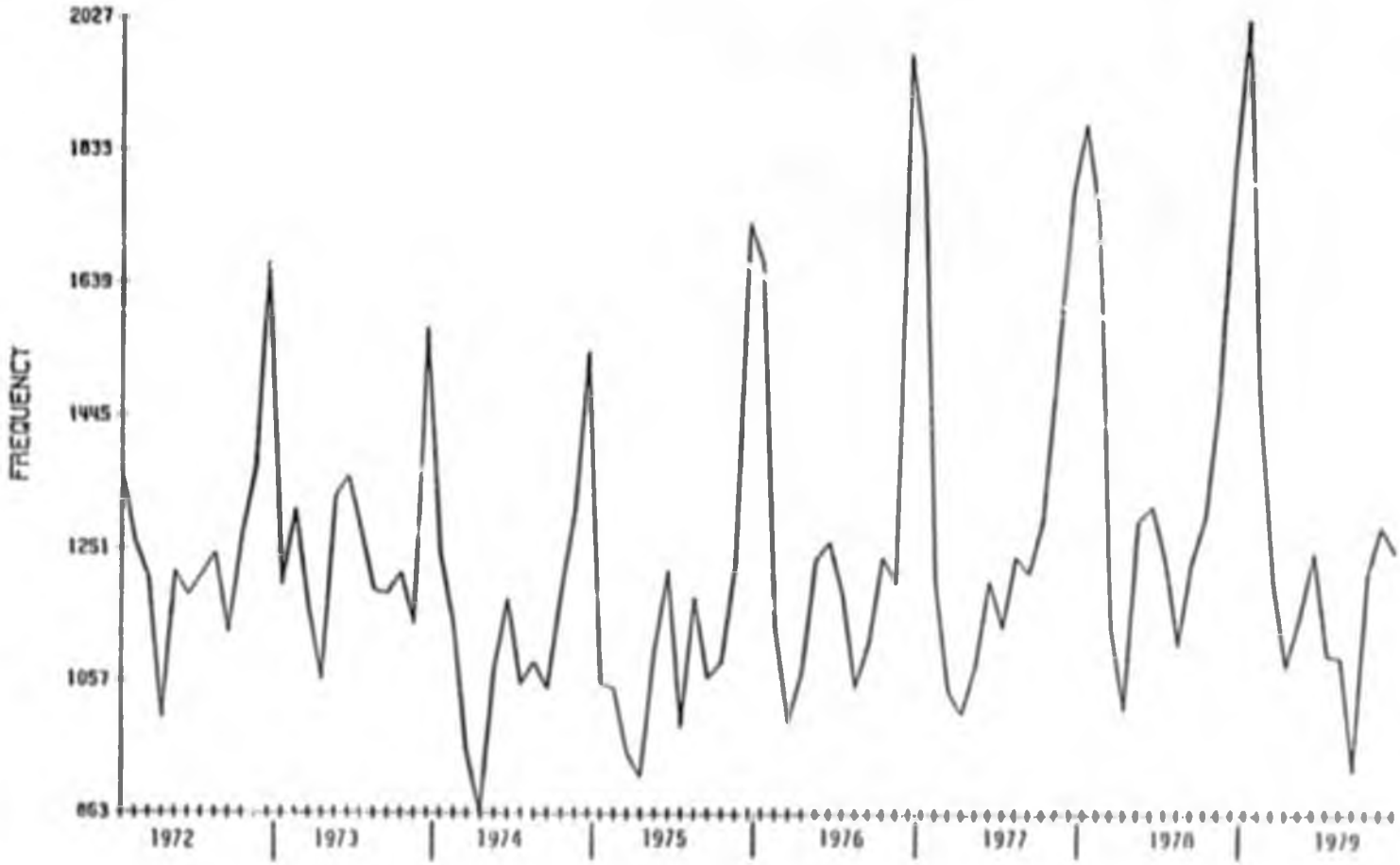

Figure 4.9 Frequency of Had-not-been-drinking Crash Involvement Among 18 - 20 Year Old Drivers in Michigan, 1972 - 1979

Table 4.7 Final Estimation Results for Combined ARIMA/Transfer Function Model of Reported Had-not-been drinking Crash Frequency Among Drivers Aged 18 - 20

Noise Model: ARIMA (1,0,0)(1,0,0)12 with no transformations
Fuel Shortage Transfer Function: rsb (0,0,0) with step function input
Raised Drinking Age Transfer Function: rsb (0,0,0) with step function input

	Parameter Estimates	Standard Errors
Fuel Shortage	ω = -86.05	73.13
Raised Drinking Age	ω = -92.05	65.59
	ϕ_1 = .33	.11
	Γ_1 = .74	.08

Residual Variance = 22,728 R-sqr = .66 Q = 25.91

Residual Autocorrelations: Approx. standard error = .11

1: .01	2:-.13	3: .19	4:-.05	5: .00
6: .02	7: .00	8: .02	9:-.09	10: .05
11: .16	12:-.17	13: .20	14: .20	15:-.19
16: .07	17: .04	18:-.11	19: .02	20:-.10
21.-.07	22:-.10	23:-.10	24: .13	

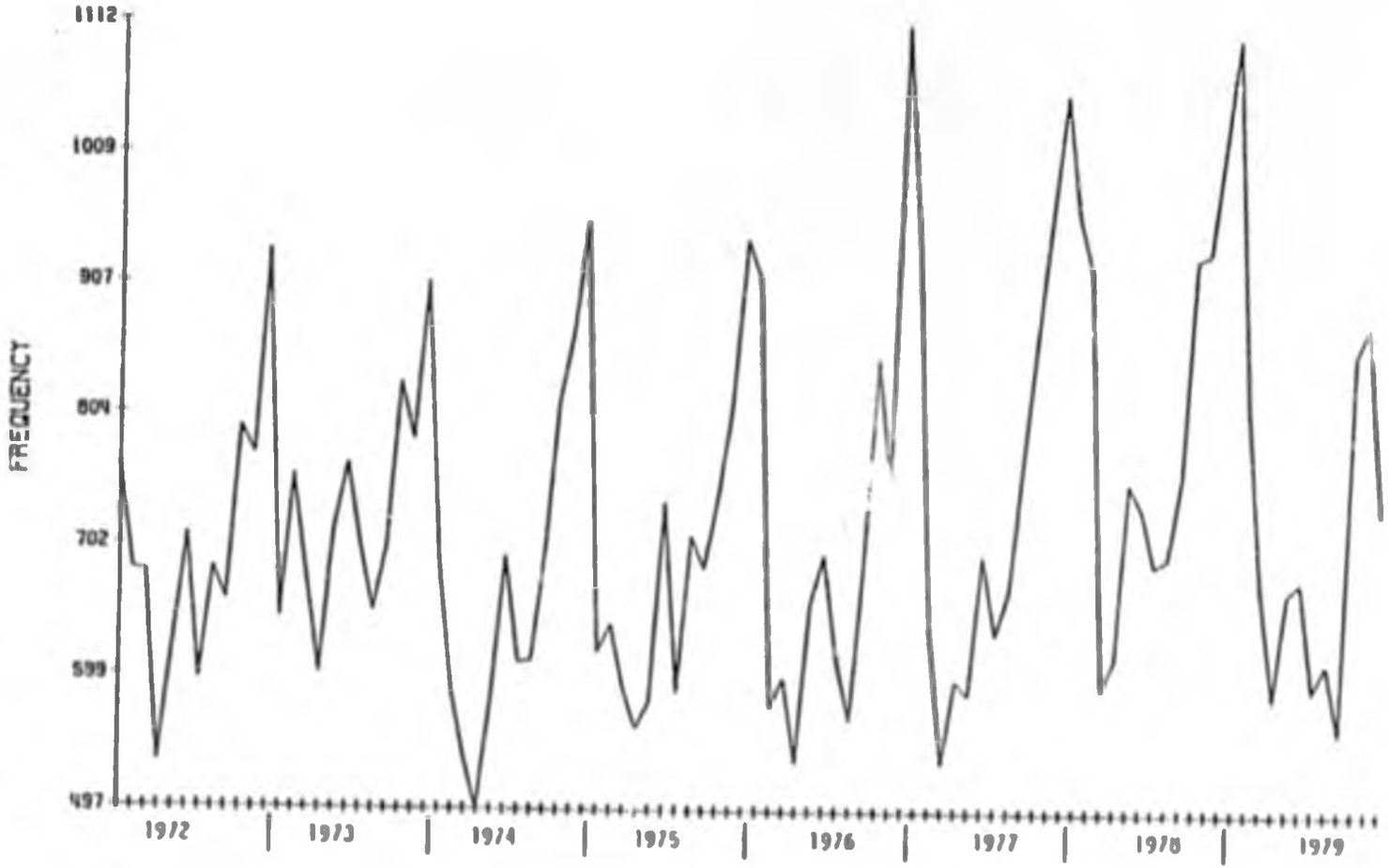

Figure 4.10 Frequency of Had-not-been-drinking Crash Involvement Among 16 - 17 Year Old Drivers in Michigan, 1972 - 1979

Table 4.8 Final Estimation Results for Combined ARIMA/Transfer Function Model of Reported Had-not-been-drinking Crash Frequency Among Drivers Aged 16 - 17

Noise Model: ARIMA (0,0,0)(1,1,0)12 with no transformations
Fuel Shortage Transfer Function: rsb (0,0,0) with step function input
Raised Drinking Age Transfer Function: rsb (0,0,0) with step function input

	Parameter Estimates	Standard Errors
Fuel Shortage	ω = -41.92	26.50
Raised Drinking Age	ω = -55.98	27.16
	Γ_1 = -.27	.13

Residual Variance = 8300 R-sqr = .68 Q = 16.42

Residual Autocorrelations: Approx. standard error = .11

1: .05	2: .13	3: .21	4: .05	5: .04
6:-.04	7:-.05	8:-.06	9: .09	10:-.03
11: .10	12:-.05	13: .14	14: .05	15:-.09
16: .07	17:-.03	18:-.06	19:-.10	20:-.06
21:-.10	22:-.20	23:-.16	24:-.04	

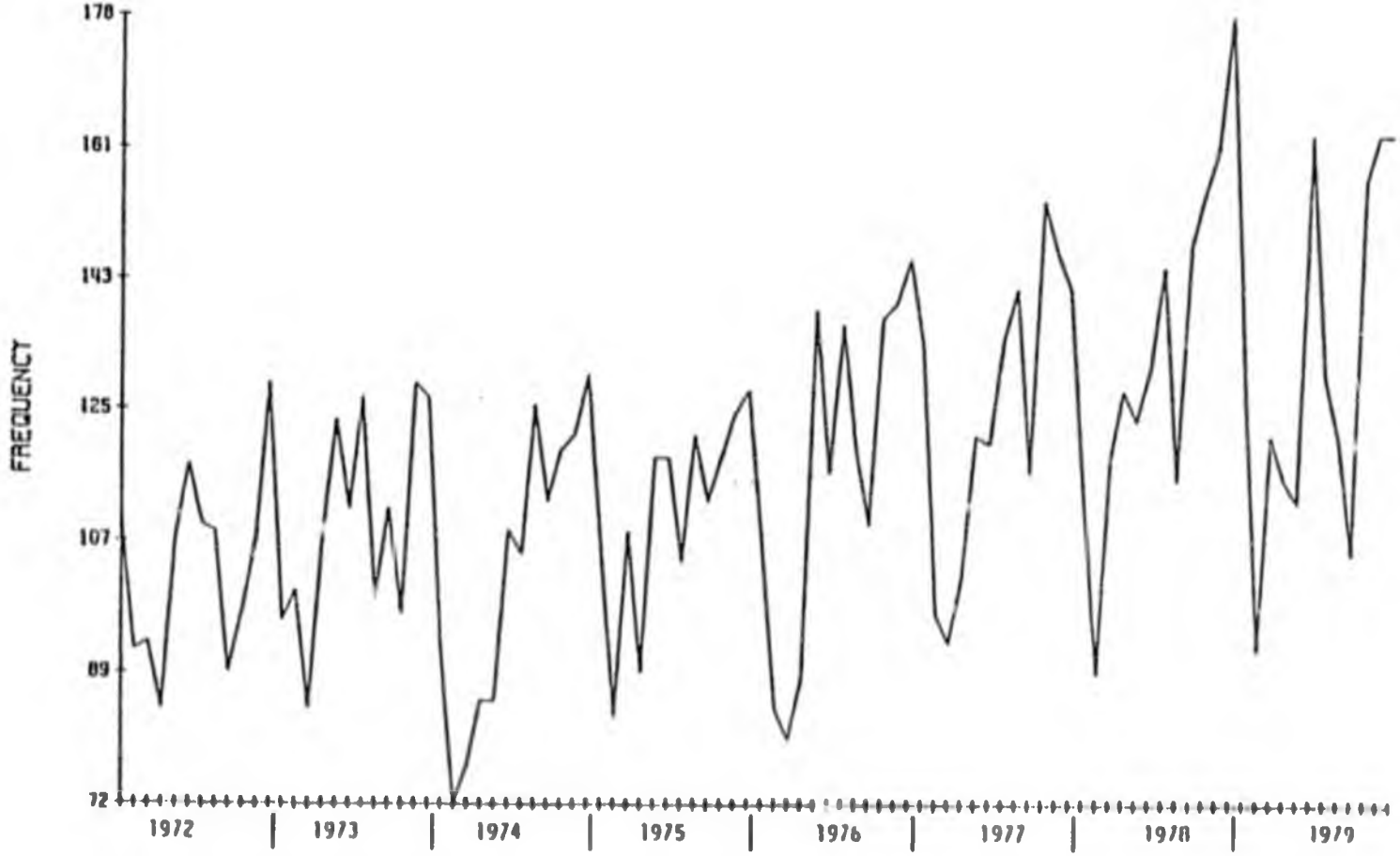

Figure 4.11 Frequency of Three-factor-surrogate Crash Involvement Among 21 - 24 Year Old Drivers in Michigan, 1972 - 1979

Table 4.9 Final Estimation Results for Combined ARIMA/Transfer Function Model of Three-factor-surrogate Crash Frequency Among Drivers Aged 21 - 24

Noise Model: ARIMA (0,0,2)(0,1,1)12 with no transformations
Fuel Shortage Transfer Function: rsb (0,0,0) with step function input
Raised Drinking Age Transfer Function: rsb (0,0,0) with step function input

	Parameter Estimates		Standard Errors
Fuel Shortage	ω =	7.07	6.14
Raised Drinking Age	ω =	2.96	6.69
	θ_1 =	-.10	.12
	θ_2 =	-.33	.12
	Δ_1 =	.50	.13

Residual Variance = 241 R-sqr = .66 Q = 20.63

Residual Autocorrelations: Approx. standard error = .11

1:-.02	2:-.09	3: .12	4:-.12	5: .01
6: .18	7: .04	8: .09	9: .11	10:-.29
11: .03	12:-.02	13:-.01	14: .16	15: .08
16: .03	17:-.03	18:-.12	19:-.03	20: .14
21: .03	22: .06	23: .15	24:-.14	

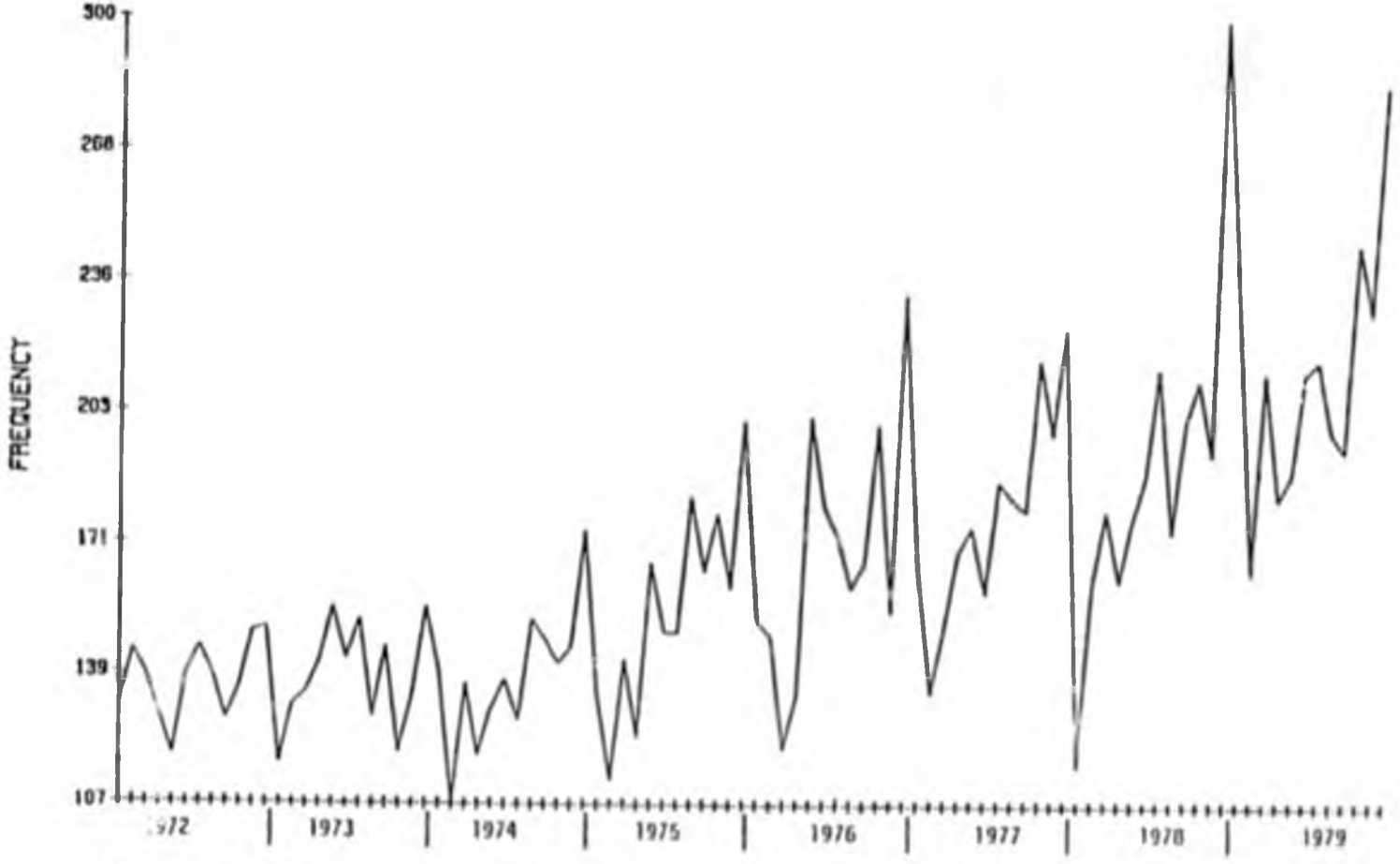

Figure 4.12 Frequency of Had-been-drinking Crash Involvement Among 21 - 24 Year Old Drivers in Michigan, 1972 - 1979

Table 4.10 Final Estimation Results for Combined ARIMA/Transfer Function Model of Reported Had-been-drinking Crash Frequency Among Drivers Aged 21 - 24

Noise Model: ARIMA (0,0,0)(1,1,0)12 with log transformation
Raised Drinking Age Transfer Function: rsb (0,0,0) with step function input

	Parameter Estimates		Standard Errors
Raised Drinking Age	ω =	.09	.05
	r_1 =	.002	.009

Residual Variance = .0247 R-sqr = .52 Q = 26.68

Residual Autocorrelations: Approx. standard error = .11

1: .08	2:-.09	3: .10	4: .08	5:-.02
6: .02	7: .18	8: .03	9: .00	10: .10
11: .05	12:-.36	13:-.06	14: .17	15:-.04
16: .03	17: .06	18:-.06	19:-.22	20:-.06
21: .05	22:-.05	23:-.10	24:-.03	

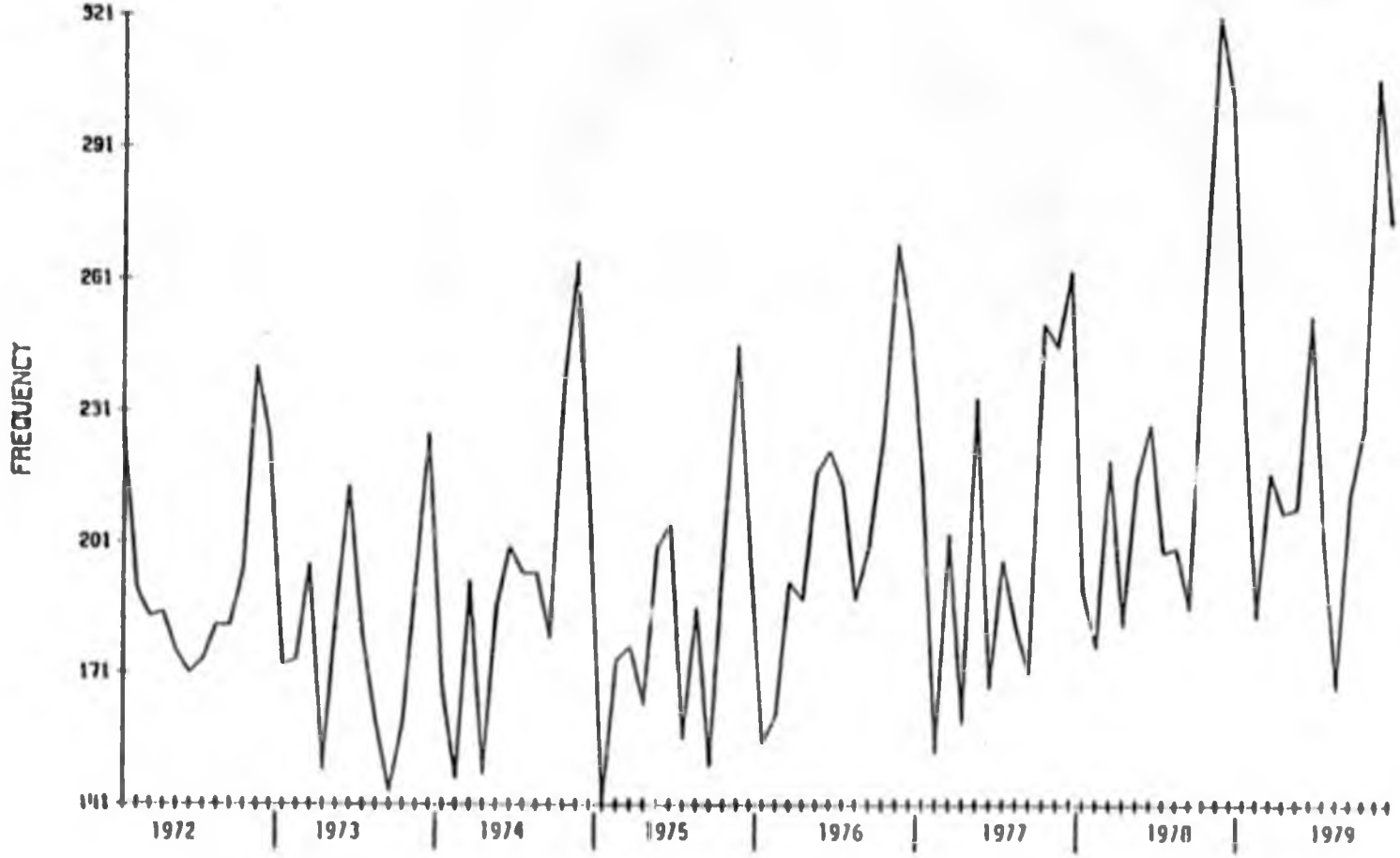

Figure 4.13 Frequency of Three-factor-surrogate Crash Involvement Among 25 - 45 Year Old Drivers in Michigan, 1972 - 1979

Table 4.11 Final Estimation Results for Combined ARIMA/Transfer Function Model of Three-factor-surrogate Crash Frequency Among Drivers Aged 25 - 45

Noise Model: ARIMA (2,0,0)(1,1,0)12 with no transformations
Raised Drinking Age Transfer Function: rsb (0,0,0) with step function input

	Parameter Estimates		Standard Errors
Raised Drinking Age	ω =	3.00	12.22
	ϕ_1 =	.09	.12
	ϕ_2 =	.35	.12
	Γ_1 =	-.44	.11

Residual Variance = 613 R-sqr = .68 Q = 21.39

Residual Autocorrelations: Approx. standard error = .11

1:-.10	2:-.05	3: .02	4:-.14	5: .04
6: .00	7: .03	8:-.02	9:-.11	10:-.01
11:-.09	12:-.07	13: .04	14:-.10	15: .07
16:-.18	17:-.06	18: .03	19:-.06	20: .09
21: .02	22:-.11	23: .33	24:-.24	

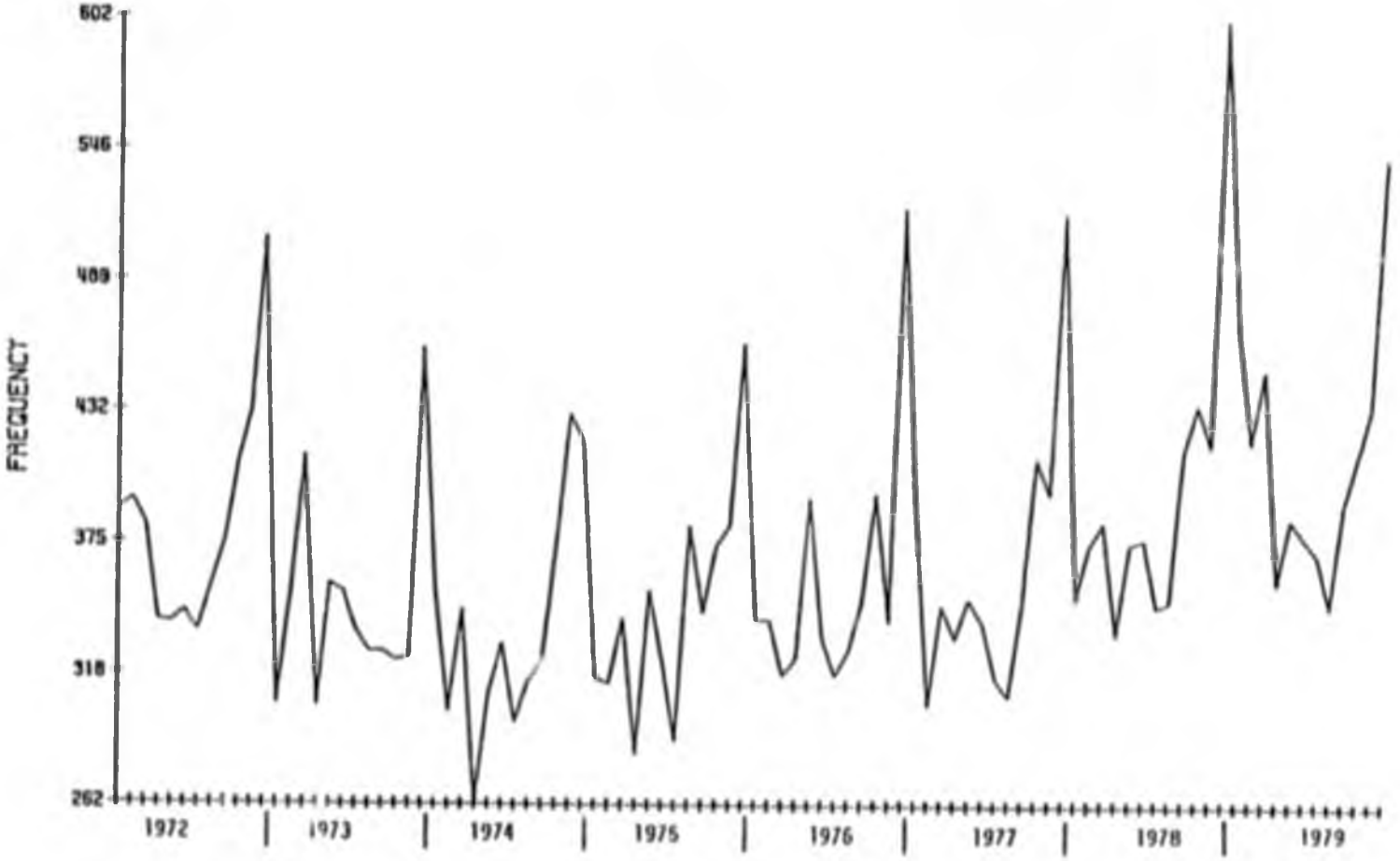

Figure 4.14 Frequency of Had-been-drinking Crash Involvement Among 25 - 45 Year Old Drivers in Michigan, 1972 - 1979

Table 4.12 Final Estimation Results for Combined ARIMA/Transfer Function Model of Reported Had-been-drinking Crash Frequency Among Drivers Aged 25 - 45

Noise Model: ARIMA (1,0,0)(1,0,0)12 with no transformations
Fuel Shortage Transfer Function: rsb (0,0,0) with step function input
Raised Drinking Age Transfer Function: rsb (0,0,0) with step function input

	Parameter Estimates	Standard Errors
Fuel Shortage	ω = -46.49	19.02
Raised Drinking Age	ω = 21.12	16.92
	ϕ_1 = .36	.10
	Γ_1 = .73	.08

Residual Variance = 1401 R-sqr = .66 Q = 17.64

Residual Autocorrelations: Approx. standard error = .11

1:-.02	2:-.04	3: .25	4: .02	5: .05
6: .11	7: .00	8:-.05	9: .02	10: .19
11: .04	12:-.16	13:-.03	14: .12	15:-.07
16:-.05	17: .05	18:-.12	19:-.02	20: .07
21:-.07	22:-.12	23: .05	24: .04	

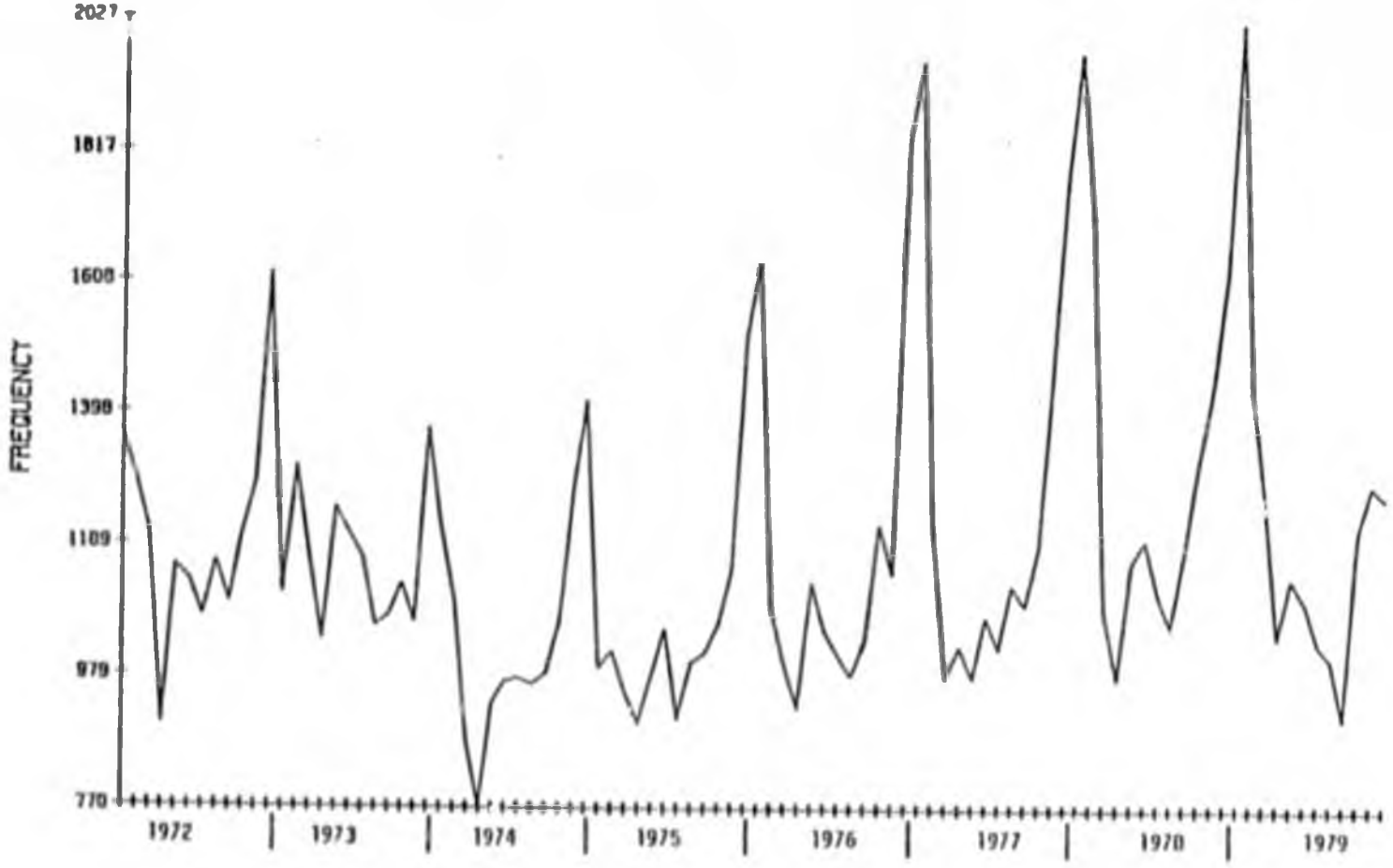

Figure 4.15 Frequency of Had-not-been-drinking Crash Involvement Among 21 - 24 Year Old Drivers in Michigan, 1972 - 1979

Table 4.13 Final Estimation Results for Combined ARIMA/Transfer Function Model of Reported Had-not-been-drinking Crash Frequency Among Drivers Aged 21 - 24

Noise Model: ARIMA (1,0,0)(1,0,0)12 with no transformations
Fuel Shortage Transfer Function: rsb (0,0,0) with step function input
Raised Drinking Age Transfer Function: rsb (0,0,0) with step function input

	Parameter Estimates	Standard Errors
Fuel Shortage	ω = -60.41	78.36
Raised Drinking Age	ω = -42.32	69.24
	ϕ_1 = .37	.11
	Γ_1 = .74	.09

Residual Variance = 23,244 R-sqr = .69 Q = 17.82

Residual Autocorrelations: Approx. standard error = .11

1: .00	2:-.04	3: .15	4: .05	5:-.04
6:-.01	7: .05	8:-.02	9:-.03	10: .07
11: .18	12:-.10	13: .26	14: .14	15:-.13
16:-.01	17: .02	18:-.06	19:-.05	20:-.09
21:-.02	22:-.07	23:-.06	24: .38	

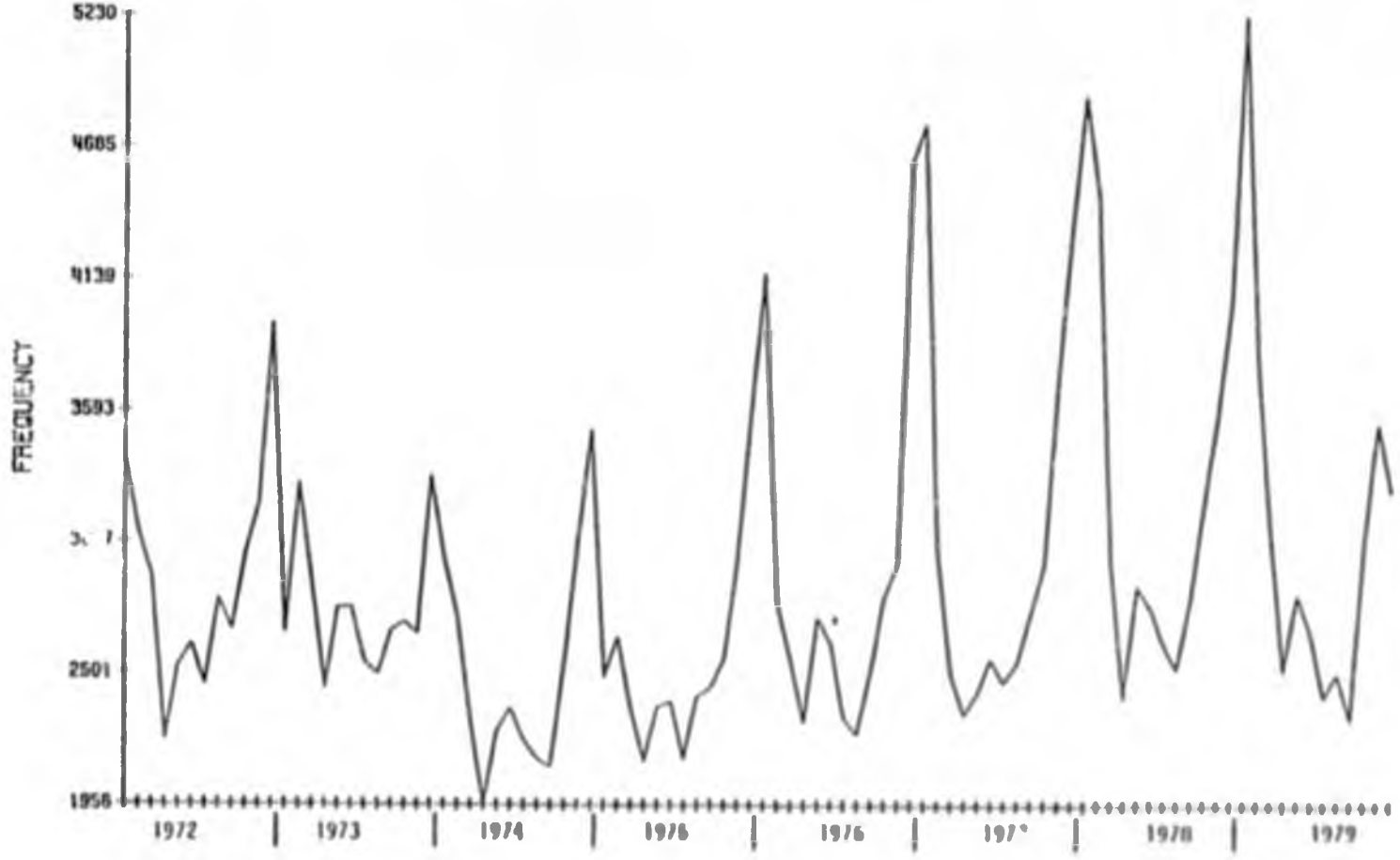

Figure 4.16 Frequency of Had-not-been-drinking Crash Involvement Among 25 - 45 Year Old Drivers in Michigan, 1972 - 1979

Table 4.14 Final Estimation Results for Combined ARIMA/Transfer Function Model of Reported Had-not-been-drinking Crash Frequency Among Drivers Aged 25 - 45

Noise Model: ARIMA (1,0,0)(1,0,0)12 with no transformations
Fuel Shortage Transfer Function: rsb (0,0,0) with step function input
Raised Drinking Age Transfer Function: rsb (0,0,0) with step function input

	Parameter Estimates	Standard Errors
Fuel Shortage	ω = -57.17	163.08
Raised Drinking Age	ω =-147.34	179.46
	ϕ_1 = .32	.11
	Γ_1 = .80	.08

Residual Variance = 145,979 R-sqr = .72 Q = 23.89

Residual Autocorrelations: Approx. standard error = .11

1: .00	2:-.03	3: .16	4: .09	5: .01
6:-.02	7: .03	8: .00	9:-.01	10: .06
11: .27	12:-.14	13: .19	14: .19	15:-.10
16:-.09	17:-.02	18:-.06	19:-.08	20:-.06
21:-.02	22:-.02	23:-.17	24: .14	

Table 4.15 Summary of Transfer Function Estimates of the Impact of the Raised Legal Drinking Age on a 20 Percent Random Sample of Motor Vehicle Crashes in Michigan

	Age of Driver			
	16 - 17	18 - 20	21 - 24	25 - 45
HNBD Crashes	-56.0 (27.2)* -7.1%	-92.0 (65.6) -6.8%	-42.3 (69.2) -3.3%	-147.3 (179.5) -4.5%
HBD Crashes	-3.4 (3.4) -7.4%	-.376 (.063)** -30.7%	.09 (.05)* +9.4%	21.1 (16.9) +5.4%
3PS Crashes	-9.5 (3.1)** -14.7%	-27.5 (8.1)** -17.7%	3.0 (6.7) +2.3%	3.0 (12.2) +1.3%

Notes:
1. Standard errors are in parentheses following each point estimate.
2. Point estimates significant at the .05 level are identified with a single asterisk, those significant at the .01 level are identified with double asterisks, using a one-tailed test.
3. Percentage change figures are included below the transfer function estimates

(Table 4.15). The frequency of 3FS crash-involved drivers was down an average of 47.25 crashes per month over the first year after the drinking age was raised. The estimated reduction of 567 crash involvements over the first 12 months following implementation of the raised drinking age (i.e. 47.25 per month for 12 months), represents a 14.74 percent decrease from what one would have expected on the basis of the 7 year baseline period.

Analyses of police-reported HBD 16-17 year old crash-involved drivers, however, indicated no significant change in frequency associated with the raised drinking age change (Table 4.15). Although not statistically significant, the raised drinking age transfer function parameter estimate was in the expected direction, with an estimated reduction of 17 HBD driver involvements per month associated with raising the legal drinking age.

Analyses of police-reported HNBD crash involvement of drivers aged 16-17 identified a significant reduction in crash frequency concomitant with the raised drinking age (Table 4.15). The estimated average reduction of 286 crash involvements per month represents 7.12 percent fewer police-reported HNBD crash-involved drivers in 1979 than one would have expected given the 1972 through 1978 baseline trends.

The finding of a significant drop in HNBD crash involvement and no significant change in HBD crashes among 16-17 year old drivers appears to indicate that raising the drinking age caused non-alcohol-related crashes to increase with no effect on alcohol-related crashes. However, it is important to remember that the HBD and HNBD variables were only indicators of the underlying concepts. In Appendix B the threats to

internal validity of instrumentation and selection-instrumentation interaction, and the threats to construct validity of "mono-operation bias" and "mono-method bias" are discussed. In short, all of these validity threats are concerned with the extent to which the indicator used (i.e. HBD/HNBD) is a consistent and valid measure of the concept "alcohol-related crash involvement." These threats to valid causal conclusions concerning the impact of the drinking age on youthful crash involvement were reduced by the inclusion of the 3FS measure of alcohol-related accidents.

In the present case, a significant drop in HNBD crash involvement and no significant change in HBD crashes was found. At face value, these findings suggest that there was a significant drop in non-alcohol-related crash involvement among drivers aged 16-17 after the drinking age was raised. A general reduction in crash involvement of the age group due to some factor unrelated to the drinking age may account for the significant drop in both HNBD and 3FS crash involvement. However, the reduction in alcohol-related crashes as measured by the 3FS variable was twice as large as the reduction in HNBD crashes, perhaps indicating that the reduction in HNBD crashes was a result of a decrease in that proportion of the HNBD series representing alcohol-related crashes that were reported as HNBD. A proportion of alcohol-related crashes among 16-17 year olds may, in fact, have been included in the HNBD series because of reluctance on the part of the investigating police officer to report the presence of alcohol in a crash involving an underage driver. In any event, support for the hypothesis was provided by analyses of the more reliable 3FS measure, and it was cautiously concluded that the raised

drinking age may have had some effect on alcohol-related collision involvement among drivers aged 16-17.

It was also hypothesized that the effect of the drinking age on drivers aged 16-17 would be less than the impact on the focal 18-20 age group. Comparisons of the analyses of the more reliable alcohol-related crash indicator, the three-factor-surrogate, for the two age groups revealed that the percentage reduction in crash frequency was somewhat smaller for the 16-17 group than for 18-20 year old drivers (Table 4.15). In addition, the decrease in HBD crashes for drivers aged 16-17 was much smaller than the decrease identified for drivers aged 18-20. The findings for the 16-17 age group, although indicative of some effect of the raised drinking age, were more ambiguous than the clearcut effects observed for the 18-20 age group, and the effect as measured by the 3FS variable was smaller in magnitude for drivers aged 16-17 than for those aged 18-20. The results were consonant with the hypothesis that a raised legal drinking age has less effect on underage drivers than those directly affected by the legal change.

In addition to examining the effect of the raised drinking age on the frequency of alcohol-related crashes among 16-20 year old drivers, the same measures of both alcohol-related and non-alcohol-related accidents were examined for older drivers. Comparisions between the crash experience of young drivers with the crash experience of older drivers controls for the possibility that observed shifts in crash involvement among young drivers were simply due to general downward shifts in collision frequencies among all drivers. Summary results of the iterative time-series modeling process for the 3FS and HBD measures of

alcohol-related crashes and the HNBD measure of non-alcohol-related crashes, for drivers aged 21-24 and 25-45, are also presented in Table 4.15. A significant increase of about 9 percent ($p<.05$) in HBD crash involvement was identified for drivers aged 21-24. Although the other measures of alcohol-related accidents for the comparison groups aged 21-24 and 25-45 revealed no significant changes, it was instructive to note that they all had positive coefficients, compared to the consistently negative coefficients for the HBD and 3FS measures for drivers under 21. The differences between the younger and older drivers can be easily seen by comparing the plot of HBD frequency for 18-20 year olds (Figure 4.6) with the plot of HBD frequency for 21-24 year olds (Figure 4.12). A clear drop occurred in 1979 for the 18-20 group, while the frequency for the 21-24 group increased. Such a pattern of findings further supports the hypothesis that the reductions in alcohol-related crash involvement for drivers under 21 was caused by some factor specific to that age group, i.e., the legal drinking age, and not a result of general reducions in alcohol-related crash involvement for all drivers.

No statistically significant changes in HNBD crash involvement were identified for drivers over the age of 21. Furthermore, an examination of non-alcohol-related crash involvement across the four age groups, revealed negative parameter estimates for all age groups (Table 4.15). Although only the estimated reduction in HNBD crash involvement for drivers aged 16-17 was statistically significant, the consistently negative estimates across all age groups indicated that there was a small reduction in general crash involvement in 1979. The raw frequency plots of HNBD crash involvement (Figures 4.9, 4.10, 4.15, and 4.16) demonstrated

the reduced HNBD frequency for all of the age groups in 1979 as compared to previous years. The economic recession in Michigan, increased motor fuel prices, and a moderate fuel shortage may account for the small reduction in overall crash involvement. The number of HNBD crash involvements for all of the age groups appeared particularly lower than expected for November and December of 1979. The unusually mild winter weather, with the concomitant lack of snow and associated driving hazards, may have caused the substantial reduction in crash frequencies in late 1979.

The implications for a determination of the causal effect of the raised drinking age was that a small part of the reduction in HBD and 3FS alcohol-related crash involvement may be due to the general reduction in crash involvement in 1979. It was clear from the pattern of findings shown in Table 4.15, however, that the general reduction in non-alcohol-related crash involvement could account for only a small portion of the statistically significant and substantial reductions in 3FS and HBD crashes among drivers under 21.

4.3 Time-series Models of Michigan Fatal Crash Frequencies, 1968 - 1979

Data on Michigan fatalities were available for the entire 1968 through 1979 period including several years prior to the lowered legal drinking age in 1972, the seven years during which the drinking age was 18, and one year after the return to a drinking age at 21. As was discussed in Section 3.2, the fatal crash frequencies were not stratified by the police reported HBD/HNBD variable because of instrument changes and data collection problems over the 1968 to 1979 time period. As a result,

the total frequency of fatalities and the frequency of alcohol-related fatalities as measured by the three-factor-surrogate were examined for each of the four age groups.

The original design called for the explicit testing of hypotheses concerning the differential effect of the lowered and raised legal drinking age using the time-series analysis methods discussed in Section 3.4. Traffic fatalities are relatively rare events, however, and the fatal crash time-series had low monthly counts, especially when stratified by age and the 3FS indices, compared to the time-series variables based on a 20 percent sample of all crashes presented in the previous section. One consequence of the low monthly frequency was a larger random error component in the series. The volatility of the fatality time-series could be seen by comparing the plots of the total crash series (Figures 4.6 through 4.16) with those of the fatality series (Figures 4.17 through 4.24). The contrast was most dramatic for the variables of primary interest, i.e., underage drinkers involved in 3FS fatal crashes (compare Figures 4.4 and 4.7 with 4.17 and 4.19). The unpredictability of the fatality time-series was also evident in the preliminary modeling of 3FS fatalities for drivers under 21. The percentage of total variance in the fatality variables accounted for was less than half the percentage accounted for by the total crash models presented in Section 4.2. As a result of these characteristics of the fatality variables, statistical time-series intervention models were not constructed. Suggestive results were based on a visual examination of the 12 year fatality time-series variables.

The time-series plot of the frequency of 3FS fatal crash

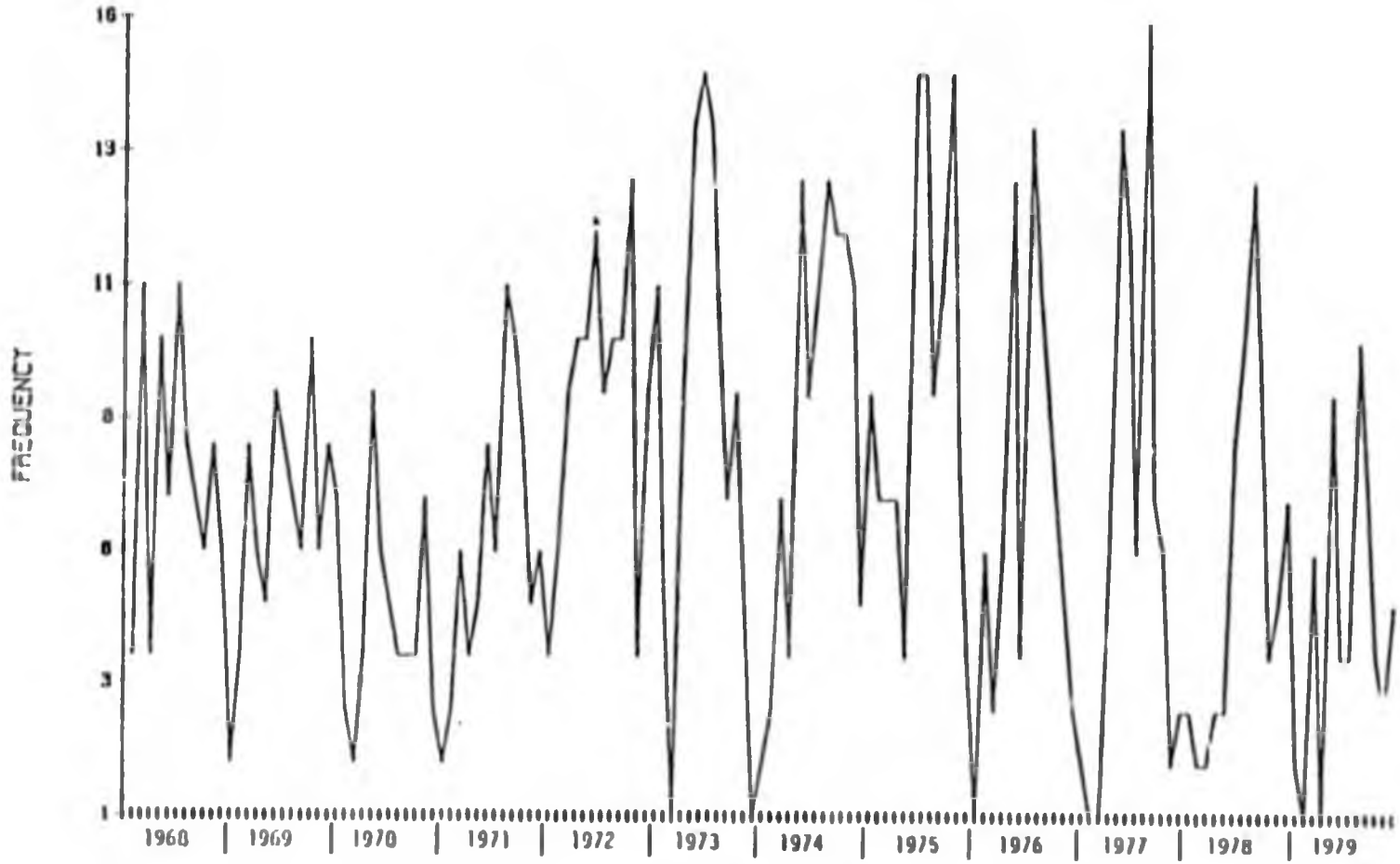

Figure 4.17 Frequency of Three-factor-surrogate Fatal Crash Involvement Among 18 - 20 Year Old Drivers in Michigan, 1968 - 1979

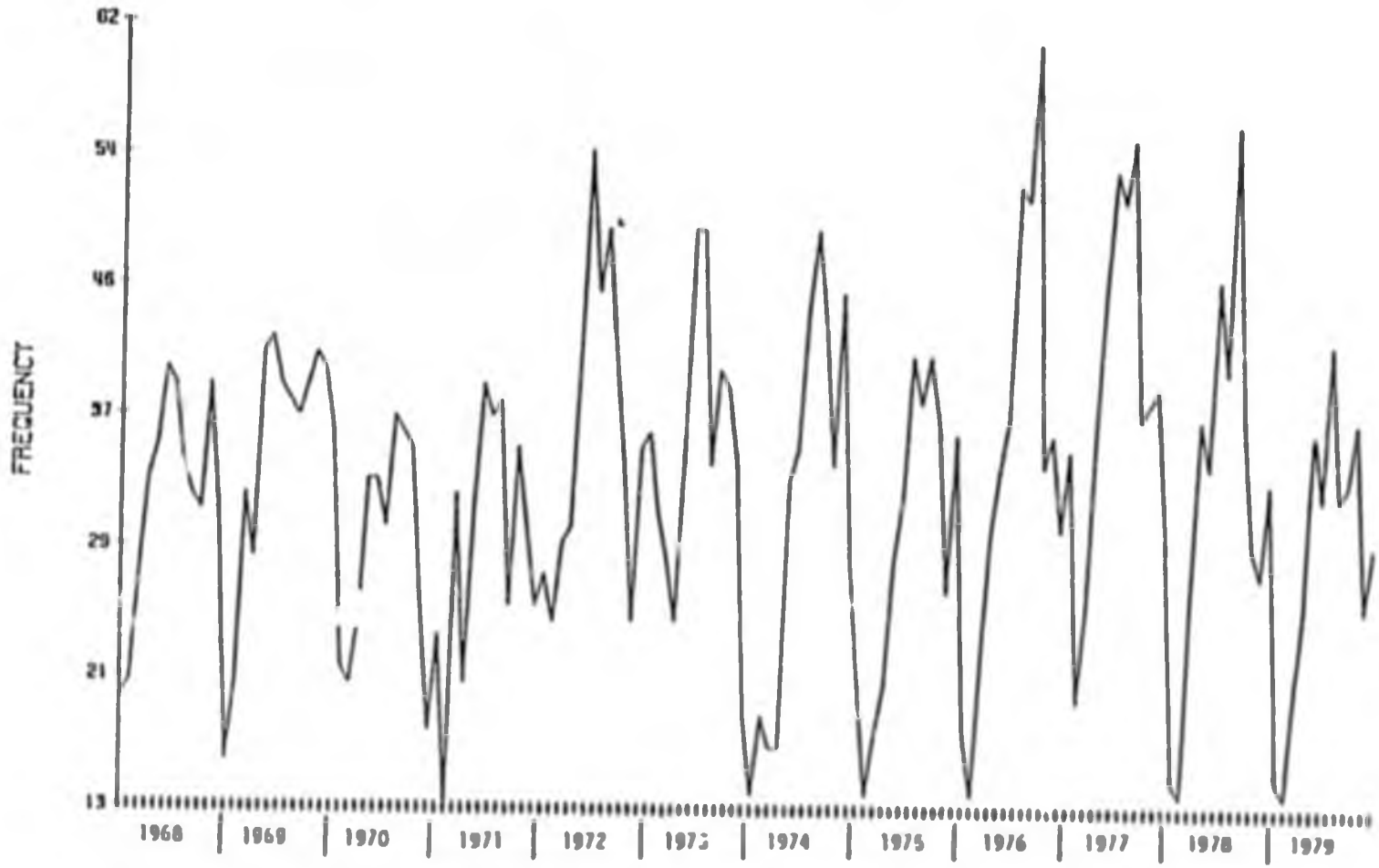

Figure 4.18 Frequency of Total Fatal Crash Involvement Among 18 - 20 Year Old Drivers in Michigan, 1968 - 1979

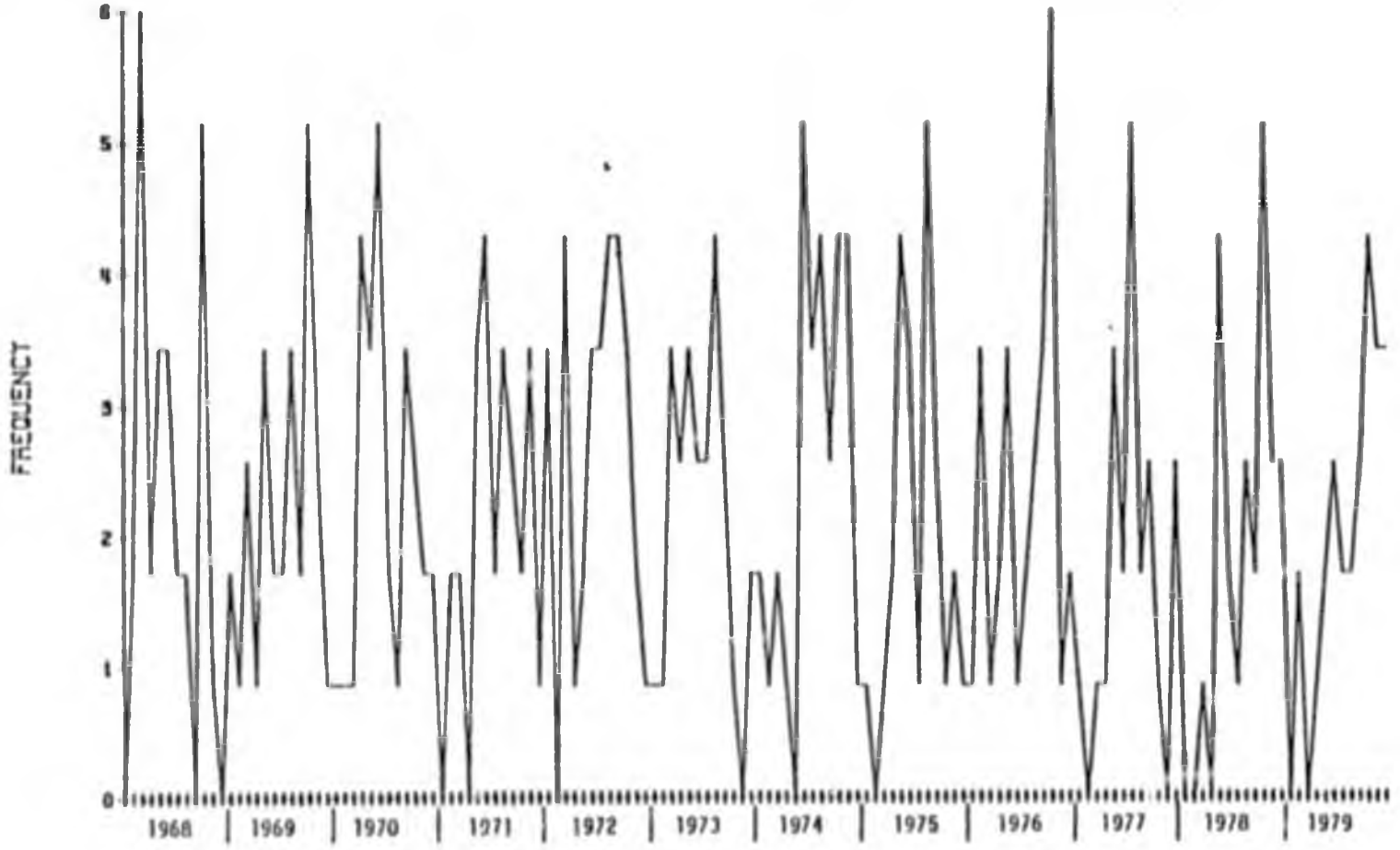

Figure 4.19 Frequency of Three-factor-surrogate Fatal Crash Involvement Among 16 - 17 Year Old Drivers in Michigan, 1968 - 1979

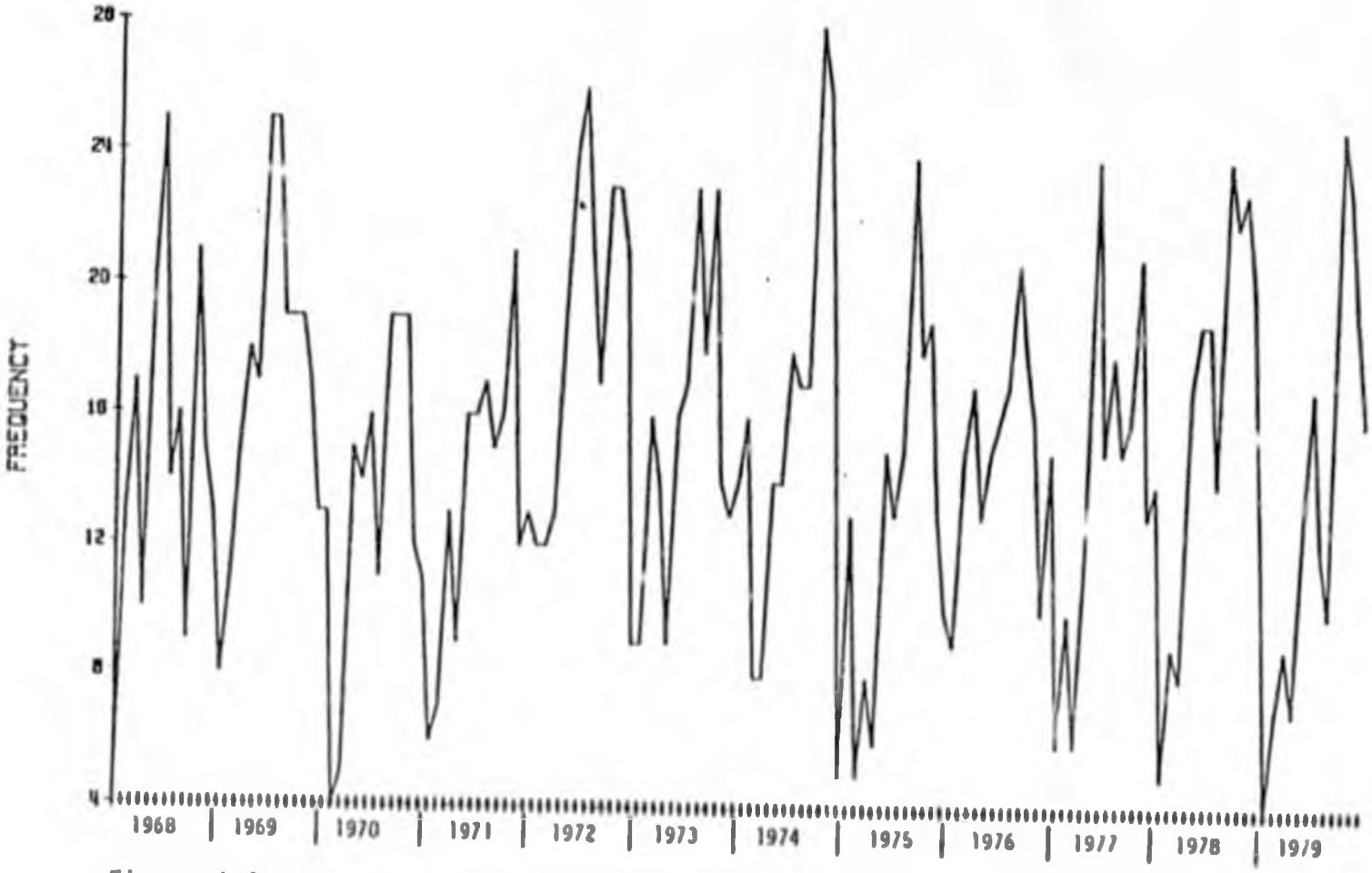

Figure 4.20 Frequency of Total Fatal Crash Involvement Among 16 - 17 Year Old Drivers in Michigan, 1968 - 1979

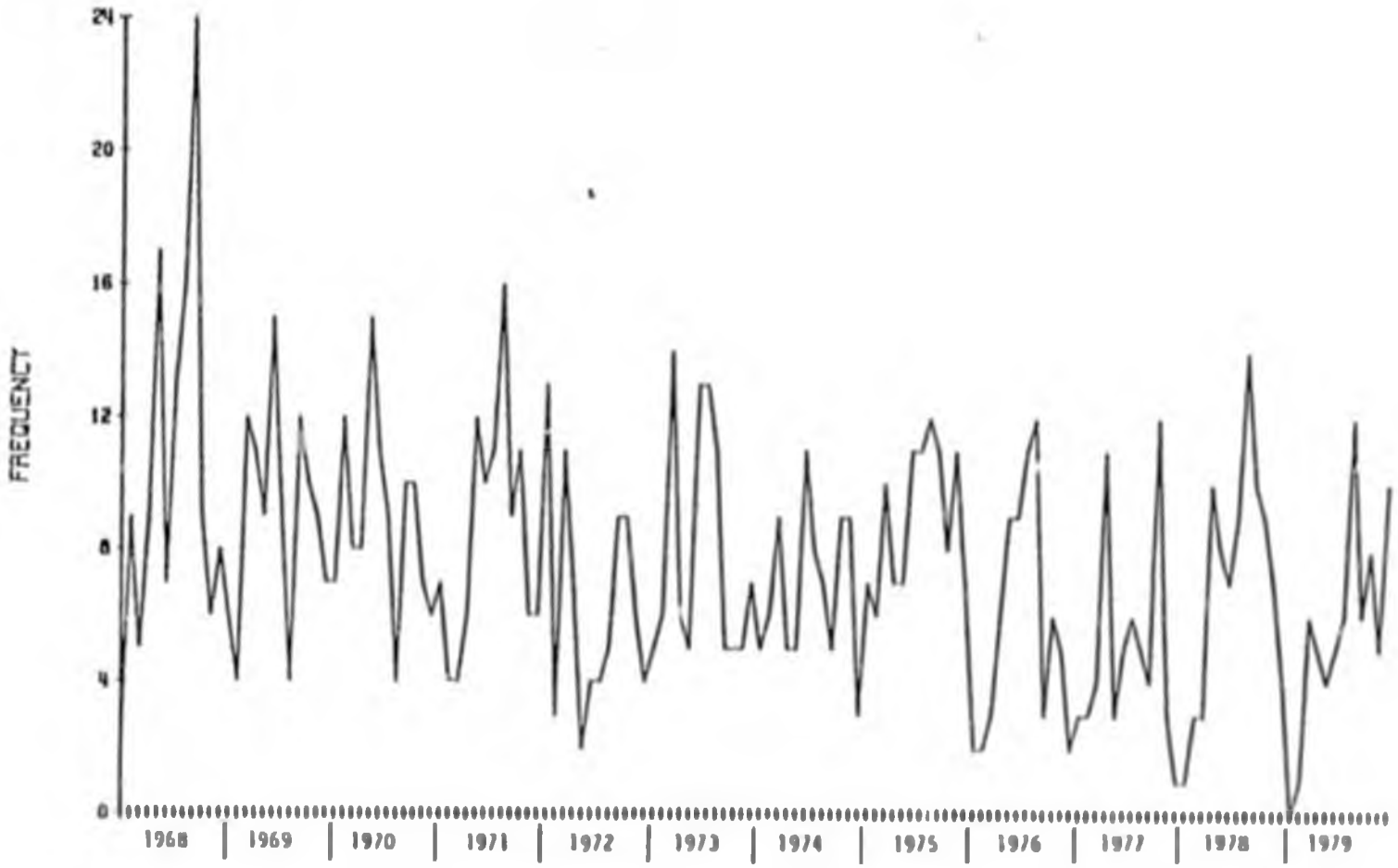

Figure 4.21 Frequency of Three-factor-surrogate Fatal Crash Involvement Among 21 - 24 Year Old Drivers in Michigan, 1968 - 1979

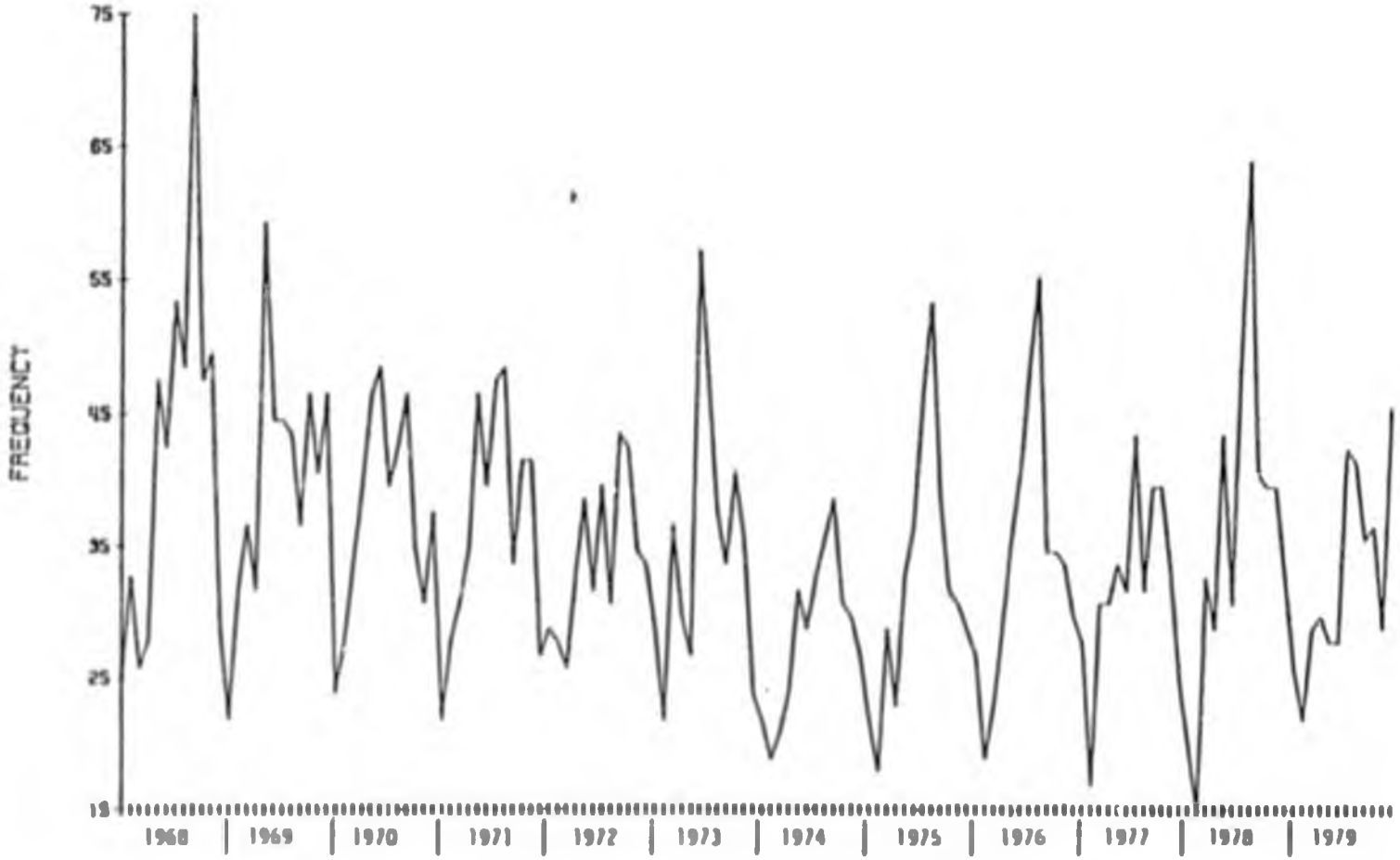

Figure 4.22 Frequency of Total Fatal Crash Involvement Among 21 - 24 Year Old Drivers in Michigan, 1968 - 1979

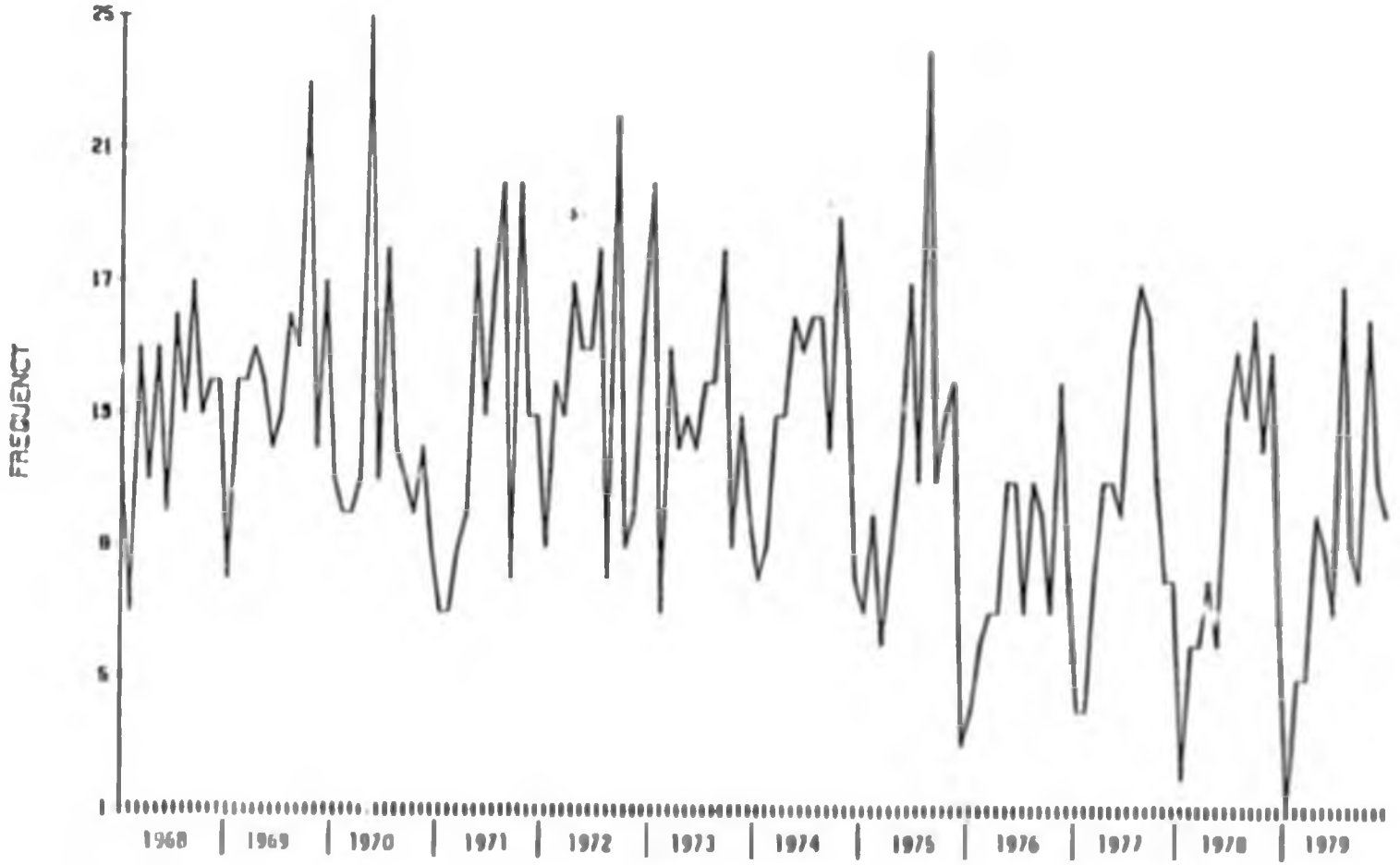

Figure 4.23 Frequency of Three-factor-surrogate Fatal Crash Involvement Among 25 - 45 Year Old Drivers in Michigan, 1968 - 1979

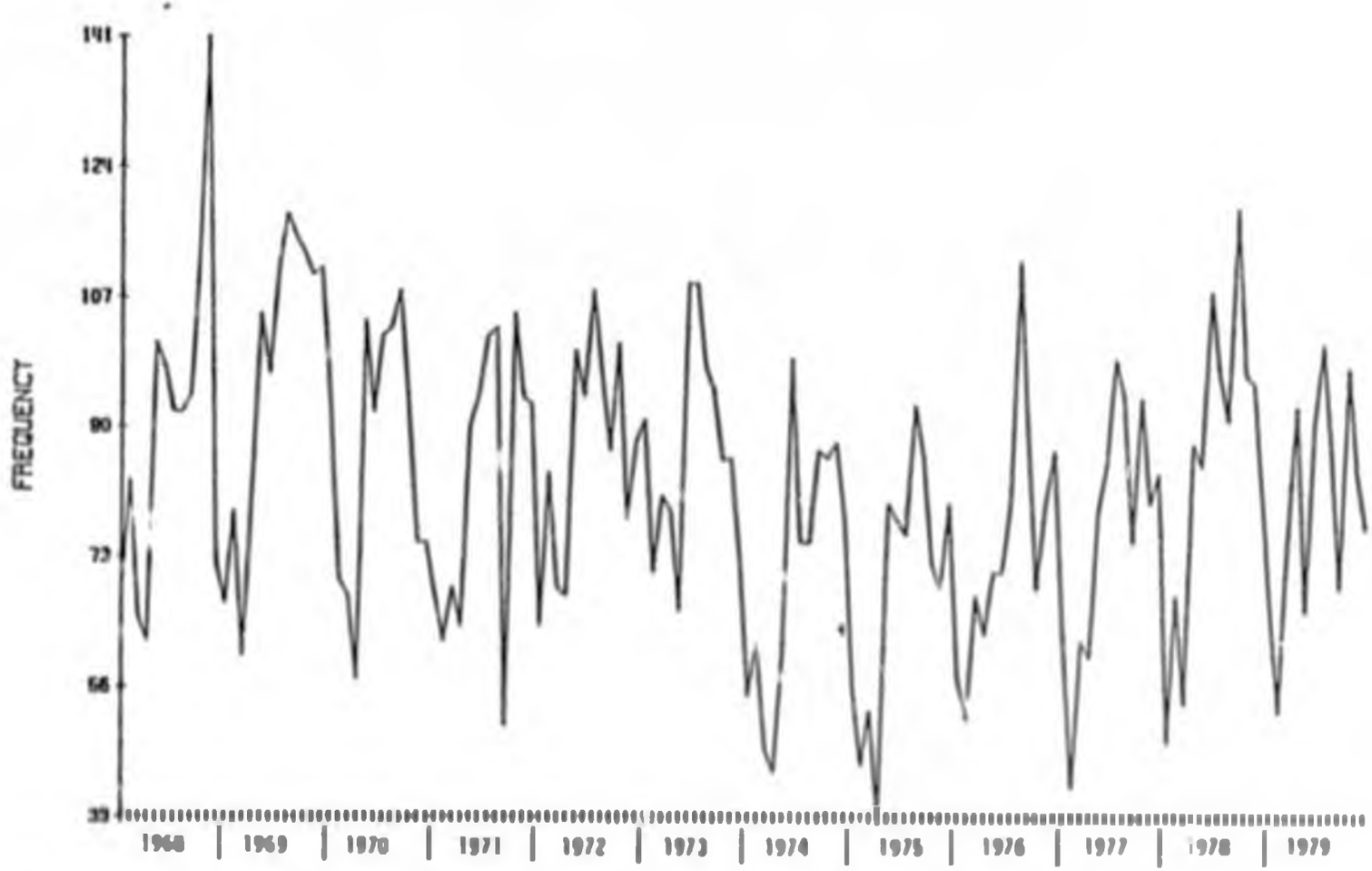

Figure 4.24 Frequency of Total Fatal Crash Involvement Among 25 - 45 Year Old Drivers in Michigan, 1968 - 1979

involvement among drivers aged 18-20 (Figure 4.17), revealed increased monthly frequencies in 1972 after the drinking age was lowered and decreased frequencies in 1979 after the legal age was returned to its pre-1972 level. One might argue that a similar pattern was evident for total fatal crash involvement among 18-20 year olds (Figure 4.18). No obvious shifts in the frequency of 3FS or total fatal crash involvement for drivers aged 16-17 were associated with the lowered drinking age in 1972 or the raised drinking age in 1978 (Figures 4.19 and 4.20). Three-factor-surrogate fatal crash involvement for drivers aged 21-24 and 25-45 did not change appreciably when the drinking age was changed. The frequency of total fatal crash involvement among the 21-24 and 25-45 groups, however, appeared to decline slightly in 1979 compared to previous years (Figures 4.22 and 4.24).

The observed changes in fatal crash frequencies based on a visual examination of the 12 year time-series plots should be interpreted very cautiously because of the large amount of "noise" or random error in the time-series. Irregular fluctuations in the frequency of alcohol-related fatalities among young drivers in Michigan made it difficult to detect small changes in the extent of the drinking-driving problem among youth using the fatal crash involvement time-series. Given the available data, it must be tentatively concluded that there was no demonstrable effect of the raised drinking age on the frequency of alcohol-related fatalities in Michigan. Further analyses of the fatality data, using yearly aggregates and alternative analysis techniques, were underway at the time this was written. (5)

A plausible explanation for the lack of a significant change in alcohol-related fatal crash involvement associated with the raised drinking age, in contrast to the findings for total alcohol-related crash involvement, might be suggested. Fatal alcohol-related crash involved drivers tend to have the highest blood alcohol concentrations of all drinking drivers. As a result, fatal alcohol-related crash involved drivers are likely to be heavier drinkers than drinking drivers involved in non-fatal crashes. It is reasonable to argue that the heaviest drinkers among the youthful drinking-driver population (i.e., those with the highest chance of being involved in a fatal crash), are the least likley to be influenced by the altered drinking norms, industry marketing practices, and alcohol availability resulting from a change in the legal drinking age (see Figure 2.9). In constrast, youthful social drinkers are less likely to have extremely high blood alcohol concentrations when driving after drinking, and therefore are more likely to be involved in a non-fatal alcohol-related collision. Youthful social drinkers are also likely to be more influenced by availability and legal norms concerning drinking than heavy drinkers. In short, if alcohol-related fatal crash involvement is viewed as an indicator of alcohol-related problems among heavier drinkers, and alcohol-related non-fatal crash involvement is viewed as an indicator of alcohol-related problems among more moderate drinkers, one could conclude that changes in the legal drinking age have a larger effect on the incidence of alcohol-related problems among moderate drinkers than on the incidence of alcohol-related problems among heavy drinkers.

In summary, since the monthly frequency of fatalities was much

less predictable than the frequency of total crashes, it was more difficult to identify significant changes in the frequency of fatal crashes associated with exogenous factors such as modifications in the minimum drinking age. Although some changes in alcohol-related fatality frequency associated with the legal drinking age were noted, they could not be confidently attributed to the legal drinking age changes. Because of their reduced usefulness for legal impact analysis using time-series methods, and because fatalities represent only a small fraction of total youthful alcohol-related crash involvement, little emphasis has been placed on the results of the separate analyses of that subset of all crashes involving one or more fatalities.

Notes to Chapter 4.0

1. See Section 3.4 for a definition of each term in the "ARIMA (1,0,0)(1,0,0)12" nomenclature.

2. The parameter starting values are based on the theoretical relationships between autocorrelations and model parameters, substituting sample autocorrelation estimates for the corresponding population values.

3. The final results of the ARIMA modeling stage for each series can be found in the Appendix.

4. Percentage figures for those variables not log transformed were calculated as follows: percent change equals $(12x_1 / x_3)100$, where x_1 equals the transfer function point estimate of change in monthly number of crash involvements associated with the intervention, x_2 equals sum of actual 20 percent sample crash involvement frequency for the 12 months of 1979, and x_3 equals $x_2 - 12x_1$, that is, the expected number of 20 percent sample crash involvements for 1979 had there been no drinking age effect. Percentage figures for those variables that were log transformed were calculated as follows (McCleary and Hay, 1980:174): percent change equals $(e^{\omega} - 1)100$.

5. The aggregation of the frequency of fatal crash involvement for one year before and one year after the raised drinking age, and assessments of the effect of the raised drinking age using alternative data analysis techniques were underway at The University of Michigan, Highway Safety Research Institute at the time this was written. The principal authors of an evaluation of the effect of the lowered drinking age on fatal crash involvement (Flora et al., 1978) used the same methods to evaluate the effect of the raised drinking age on fatalities. Although the method does not control for long term patterns in the outcome variables, it avoids some of the problems encountered when analyzing fatalities in a time-series design.

5.0 THE RAISED LEGAL DRINKING AGE AND AGGREGATE ALCOHOL CONSUMPTION IN MICHIGAN

Although assessments of the effects of changes in the legal drinking age have largely been concerned with the incidence of motor vehicle collisions among youth, a major intervening variable between legal drinking age modifications and changes in the frequency of alcohol-related traffic collisions is the amount and pattern of youthful alcohol consumption (see Figure 2.9). In this chapter, the limited research on changes in youthful alcohol consumption following reductions in minumum age of purchase statutes is reviewed, and changes in aggregate beverage alcohol sales in Michigan associated with the raised drinking age are examined.

5.1 Literature Review

Existing literature on the effects of changing the drinking age on youthful alcohol consumption has focused on three main types of alcohol consumption data: (A) self-reported consumption, (B) perceptions of youthful consumption patterns reported by school officials, and (C) aggregate sales volumes. Wolfe and Chapman (1973a, 1973b) surveyed Michigan high school students in 1971 before the drinking age was lowered, and again in 1973 after the reduction in the drinking age, and found substantially increased frequency of drinking, and increased quantity consumed per occasion. According to the authors, the increases were consistent with pre-existing trends in youthful alcohol use, and therefore

could not be unambiguously attributed to the lowered legal drinking age.

Smart and Schmidt (1975) conducted a similar before and after survey of Toronto junior and senior high school students. After a reduction in the drinking age, 41 percent of the students reported no change in drinking patterns, 20 percent reported drinking more, 4 percent reported drinking less, and 9 percent indicated that they had started drinking since the drinking age had been reduced. Smart and Schmidt also surveyed college students, the majority of whom reported no change in frequency or quantity of alcohol consumption, although 55 percent did report increased patronization of public drinking establishments since the legal change.

McFadden and Weschler (1979) surveyed Massachusetts teenagers in 1965, 1970, and 1974. Youthful alcohol consumption increased between 1965 and 1970, when there was no change in the drinking age, as well as between 1970 and 1974, when there was a reduction in the legal age from 21 to 18. (1) The authors also surveyed New England college students in 1977, and found that students from states with a low legal drinking age consumed alcohol more frequently than students from states with a high drinking age.

Rooney and Swartz (1977) surveyed high school students in three selected states with minimum legal drinking ages at 18, and two selected states with drinking ages at 20 and 21, respectively. The samples were not demonstrably representative of the high school aged population in the states examined. They found that 42 percent of the students in states with the drinking ages at 20 or 21, and 47 percent in states with the drinking age at 18, reported consuming beer once a week or more.

Furthermore, students in states with a high drinking age had a lower prevalence of abstainers (19 versus 24 percent), and a higher incidence of alcohol-related problems. The authors concluded that a high drinking age has no beneficial effect in controlling alcohol consumption among young people, and that it may even have adverse effects.

Opposite results were obtained by Maisto and Rachal (1980) in their analyses of a nationwide probability sample of high school students. They found that students in states with a higher legal drinking age were more likely to be abstainers, less likely to be heavy drinkers, and experienced intoxication less frequenctly than students in states with a lower drinking age. The authors concluded that the legal availability of beverage alcohol, as reflected in the drinking age, is associated with the drinking practices of young people.

Perceptions of school officials have also been used as an indicator of changes in youthful alcohol consumption concomitant with lowering the drinking age. Hammond (1973), questioning 354 Michigan high school principals, found that the majority reported more drinking among 15-17 year old students after the drinking age was lowered. A similar survey in the Toronto area found that vice-principals reported more drinking among students at school functions after the drinking age was lowered (Smart and Schmidt, 1975).

The third major type of data that has been used to assess the impact of reduced drinking ages on alcohol consumption patterns is aggregate sales volumes. Smart and Schmidt (1975), in a comparison of Ontario beverage alcohol shipments before and after a reduction in the legal age, found that consumption in the first five months after the legal

change was higher than expected on the basis of the pre-change figures. Increased alcohol sales were particularly obvious for on-premise sales, strengthening the argument that the lowered drinking age was at least a partial cause of the observed changes.

Barsby and Marshall (1977), examining aggregate distilled spirits sales in 25 states, did not identify any significant impact of lowered legal purchase ages on spirit sales. The authors temper their conclusions, however, by noting four limitations of their study. First, any change in distilled spirits consumption by youth following drinking age changes would have to be substantial before the impact would be seen in the aggregate statistics. Second, very little is known about changes in consumption patterns after legal changes; a change in location or quantity consumed per occasion resulting from the lowered drinking age, for example, could have significant adverse health consequences, independent of the total quantity consumed. Third, the analyses were applied only to distilled spirits, not beer or wine, which are more popular beverages among young drinkers. Fourth, the time-span covered by the study was short, including only one year before and one year after the legal changes.

Douglass and Freedman (1977) avoided the last two design limitations of Barsby and Marshall's study by examining the monthly aggregate sales of draught beer, packaged beer, wine, and distilled spirits in Michigan over an eight year period. A statistically significant increase in draught beer sales was associated with lowering the drinking age. The authors attributed the shift in draught beer sales to the lowered drinking age, since no other confounding factors were

identified that could have plausibly accounted for the observed relationship. No significant shifts were identified for any of the other beverage categories.

Smart and Goodstadt (1977) discussed a study conducted by Smart and Finley in which per capita beer consumption in ten Canadian provinces was examined. Eight provinces that lowered their drinking ages were compared with two that hac not changed during the study period. Although increased beer sales were evident in the pre-post comparisons for three provinces experiencing a reduction in the drinking age, the increases were similar in magnitude to the experience of the two control provinces. Moreover, beer sales decreased in the other five provinces. Smart and Goodstadt conclude that the study's findings do not allow any general conclusion as to the effect of lowered drinking ages on total beer sales.

Finally, Smart (1977) compared sales of beer, wine, and distilled spirits in 25 states which reduced the drinking age with 25 states with unchanged drinking ages. Although no significant differences between the states were identified for wine or distilled spirits, increases in beer sales were about six percent greater in the states with lowered drinking ages than states with an unchanged legal age.

The existing literature concerning the effect of reduced legal drinking ages on beverage alcohol consumption among youth has significant methodological limitations and provides inconsistant results. Even less is known about the effect of raising the drinking age, in spite of a definite trend toward a higher minimum alcohol purchasing age in recent years. To help fill the gaps in present knowledge, an examination of monthly aggregate beer and wine distribution volumes in the State of

Michigan was conducted.

5.2 Method

Data obtained from the Michigan Beer and Wine Wholesalers Association were used to construct monthly time-series of the aggregate volumes of packaged beer, draught beer, and wine distributed in the State of Michigan. These data were obtained for the eleven year period from January of 1969 through February of 1980 (see Figures 5.1, 5.2, and 5.3). Long series of observations were required to assess the degree to which beverage distribution volumes in 1979, after the drinking age was raised, were different from what would have been expected given the long term patterns in apparent alcohol consumption.

Shifts in the volume of beverage alcohol distributed in Michigan at the time the drinking age was raised could have been statistically tested using the Box-Jenkins intervention analysis techniques discussed in Section 3.4. However, because of confounding events coincident with the raised drinking age, and because of the lack of age specific alcohol consumption data, simple shifts in aggregate alcohol sales associated with the raised drinking age were not expected. Without age-specific alcohol consumption data, conclusions concerning the effect of the drinking age on the drinking practices of youth must be made cautiously. If changing the drinking age does influence consumption among young people, such an effect would have to be large before it would be evident in the aggregate sales data. Therefore, rather than a hypothesis testing analysis, such as was reported in Chapter 4.0, an exploratory examination of changes in alcohol distribution during 1979 and early 1980 was conducted.

The data analyses began with a careful examination of each time-series plot for changes in the aggregate sales of alcoholic beverages associated with raising the legal drinking age. In addition to visual examinations of the raw data plots, the general multiplicative seasonal Auto Regressive Integrated Moving Average (ARIMA) time-series modeling strategy developed by Box and Jenkins (1976) was used to build a parsimonious model that adequately accounted for the pattern of autocorrelation in each variable. The iterative specification, estimation, and evaluation modeling strategy was applied to the 1968 through 1978 baseline period of each time-series. The resulting models were used to forcast beverage distribution for 1979 and early 1980 and the actual distribution figures were compared to the forecasted values. Substantial deviations of the actual distribution volumes from the forecasted values based on previous distribution patterns were considered indicative of the effects of exogenous factors such as the increase in the legal drinking age, the ban on non-returnable beverage containers, and the Michigan economic downturn of 1979. (2)

5.3 Results

A Seasonal Auto-Regressive-Integrated-Moving-Average model was identified as the best description of wholesale packaged beer shipments from 1969 through 1978 (Figure 5.1). The identified ARIMA model, shown in Table 5.1, was used to forecast packaged beer distribution for the subsequent 14 months. A comparison of the forecasted and actual values (Table 5.2), indicated that the actual packaged beer distribution for 10 of the 14 post drinking age change months were 5 to 20 percent lower than

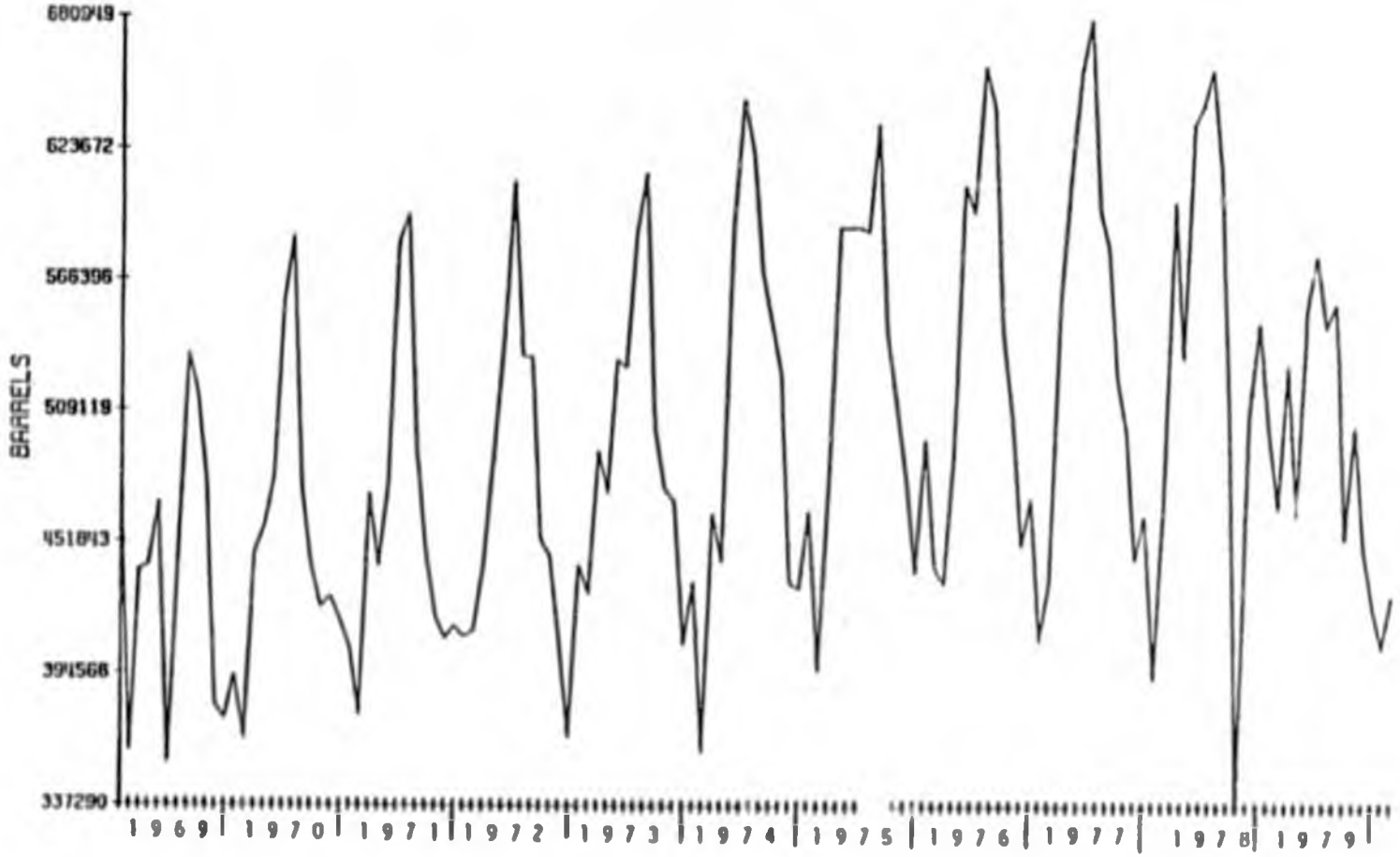

Figure 5.1 Wholesale Distribution of Packaged Beer in the State of Michigan: January 1969 through February 1980

Table 5.1 Estimated Baseline Model of Packaged Beer Distribution: January 1969 Through December 1978

Model Form: ARIMA $(1,0,0)(1,1,0)_{12}$ with no transformations

Parameter Estimates	95 Percent Confidence Interval
ϕ_1 = .2576	.0661 to .4491
Γ_1 = -.4022	-.6000 to -.2044

Q-statistic = 16.54 with 18 degrees of freedom

R^2 = .65

Table 5.2 Comparison of Forecasted and Actual Packaged Beer Distribution: January 1979 Through February 1980

Month	Percent Change	Actual Value	Forecasted Value	95 Percent Confidence Interval
January	+18.77	500,590	421,480	324,130 - 518,830
February	+1.56	467,930	460,720	360,190 - 561,250
March	-9.37	530,220	585,030	484,290 - 685,770
April	-17.93	464,500*	565,980	465,230 - 666,740
May	-13.87	555,220	644,600	543,850 - 745,360
June	-12.13	578,620	658,530	557,770 - 759,200
July	-13.78	546,980	634,440	533,690 - 735,200
August	-7.45	557,570	602,480	501,720 - 703,230
September	-12.01	454,620	516,700	415,940 - 617,450
October	+24.71	503,320	403,590	302,830 - 504,340
November	-6.71	450,190	482,680	381,920 - 583,430
December	-17.42	424,990	514,650	413,900 - 615,410
January	-.70	407,490	410,370	294,050 - 526,690
February	-7.41	429,640	464,030	346,750 - 581,310

*Significantly different from forecasted value with $p \leq .05$.

expected given the baseline data.

Important deviations from the overall pattern of lower than expected packaged beer distribution were present. First, the actual distribution for October 1979 was about 25 percent higher than forecasted. The forecasted value for October 1979 was low because of the unusually low volume for October 1978. Since the year immediately prior to the forecast (i.e. the last year of the baseline period) has a disproportionate influence on the forecast values, the unusually low volume for October 1978 caused a low forecast for October 1979. As a result, the actual October 1979 distribution was 25 percent higher than the forecast.

A second deviation from the overall reduction in packaged beer distribution was a 19 percent higher than forecasted volume for January 1979. The distribution volume in February 1979 was also higher than predicted, although only marginally (1.6 percent). As a result of the higher than expected distribution volumes for the early months of 1979, and the lower than predicted distribution for the summer months, the variation in packaged beer distribution was substantially less in 1979 compared to the baseline years.

In short, two changes in the volume of packaged beer distribution in Michigan were found when comparing the first 14 months after the drinking age was raised to the previous 10 year period. First, an overall reduction in packaged beer distribution was evident. Second, higher than forecasted distribution for the first two months of 1979 combined with lower than forecasted distribution volume for the summer months, resulted in a reduction in the seasonal variation in apparent

packaged beer consumption.

The aggregate distribution of draught beer (Figure 5.2) from 1969 through 1978 was also modeled with a specific form of the general seasonal multiplicative ARIMA model. The identified baseline model (Table 5.3) was used to generate the forecasts presented in Table 5.4. An examination of the time-series plot and the "percent change" column of Table 5.4 indicated that there was an overall increase in draught beer distribution in the first 14 months after the legal drinking age was raised. (3) Only three months deviated from the pattern of increased draught beer sales; sales were lower than forecasted in February, March, and November of 1979. The deviations from the pattern of increased draught beer consumption were small, however, and were attributed to random error.

A first-order moving average model was identified as the best description of wine distribution in Michigan from 1969 through 1978 (Figure 5.3). Using this baseline model (Table 5.5), the forecasts presented in Table 5.6 were generated. The actual values were generally lower than forecasted, indicating a reduction in wine distribution from what one would have expected given previous trends. An initial examination of the time-series plot (Figure 5.3) might lead one to conclude that there was no change in total wine distribution after the drinking age was raised in December of 1978. The reduction in wine distribution was evident in Table 5.6 because the model on which the forecasts were based included a significant constant term equal to 2408 gallons per month, representing the slope of the baseline trend. Since the forecasting model assumed the baseline trend evident over the 1969

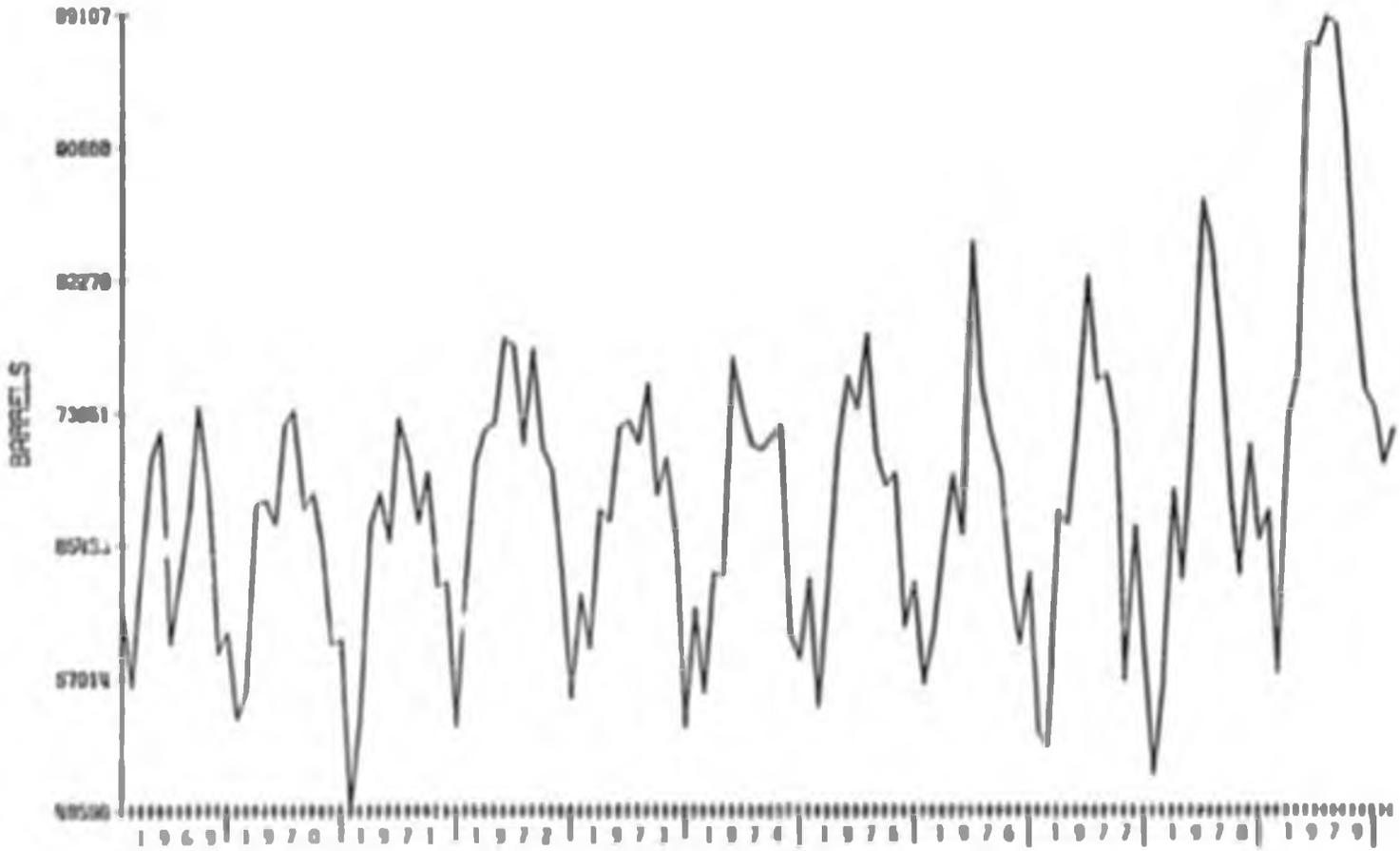

Figure 5.2 Wholesale Distribution of Draught Beer in the State of Michigan: January 1969 through February 1980

Table 5.3 Estimated Baseline Model of Draught Beer Distribution: January 1969 Through December 1978

Model Form: ARIMA $(2,1,0)(1,1,0)_{12}$ with no transformations

Parameter Estimates	95 Percent Confidence Interval
$\phi_1 = -.6783$	-.8546 to -.5020
$\phi_2 = -.4463$	-.6204 to -.2723
$r_1 = -.2314$	-.4303 to -.0325

Q-statistic = 22.66 with 17 degrees of freedom

$R^2 = .57$

Table 5.4 Comparison of Forecasted and Actual Draught Beer Distribution: January 1979 Through February 1980

Month	Percent Change	Actual Value	Forecasted Value	95 Percent Confidence Interval
January	+18.13	67,816	57,409	46,883 - 67,935
February	-7.25	57,427	61,918	50,800 - 73,036
March	-1.25	73,698	74,631	62,933 - 86,329
April	+9.24	76,690	70,205	56,780 - 83,630
May	+20.97	97,437*	80,548	56,352 - 94,744
June	+5.52	97,346	92,252	77,315 - 107,190
July	+12.41	99,107	88,165	72,256 - 104,070
August	+18.33	98,727	83,434	66,783 - 100,080
September	+21.92	92,339	75,740	58,375 - 93,105
October	+20.11	81,571	67,915	49,800 - 86,031
November	-1.46	75,532	76,650	57,857 - 95,443
December	+6.02	74,351	70,130	50,682 - 89,579
January	+14.72	70,825	61,738	38,422 - 85,054
February	+9.59	72,929	66,546	41,999 - 91,093

*Significantly different from forecasted value with $p \leq .05$.

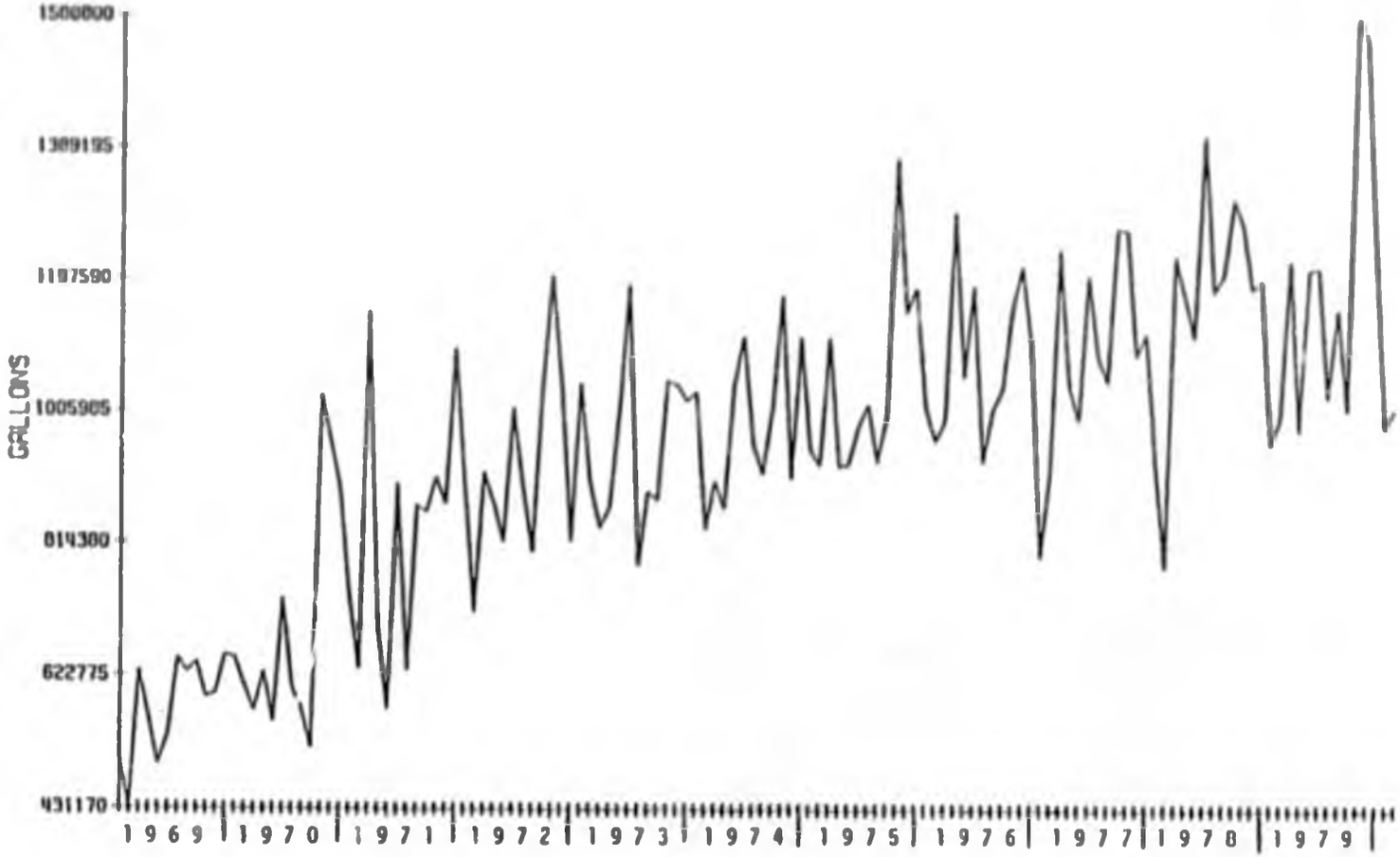

Figure 5.3 Wholesale Distribution of Wine in the State of Michigan: January 1969 through February 1980

Table 5.5 Estimated Baseline Model of Wine Distribution: January 1969 Through December 1978

Model Form: ARIMA (0,1,1)(0,0,0) with no transformations

Parameter Estimates	95 Percent Confidence Intervals
θ_1 = .9027	.8171 to .9882
α = 5608	2936 to 8281

Q-statistic = 23.32 on 18 degrees of freedom

R^2 = .63

Table 5.6 Comparison of Forecasted and Actual Wine Distribution: January 1969 Through February 1980

Month	Percent Change	Actual Value	Forecasted Value	95 Percent Confidence Interval
January	-21.59	960,830*	1,225,400	962,120 - 1,488,700
February	-19.23	994,280	1,231,000	966,490 - 1,495,500
March	-.89	1,225,600	1,236,600	970,860 - 1,502,400
April	-21.10	980,130	1,242,200	975,230 - 1,509,200
May	-2.70	1,214,100	1,247,800	979,620 - 1,516,000
June	-3.00	1,215,800	1,253,400	984,000 - 1,522,900
July	-18.39	1,027,400	1,259,000	988,400 - 1,529,700
August	-8.68	1,154,900	1,264,700	992,800 - 1,536,500
September	-20.51	1,009,700	1,270,300	997,200 - 1,543,300
October	+23.90	1,580,800*	1,275,900	1,001,600 - 1,550,100
November	+20.98	1,550,400	1,281,500	1,006,000 - 1,556,900
December	-3.92	1,236,700	1,287,100	1,010,400 - 1,563,700
January	-23.87	984,140*	1,292,700	1,014,900 - 1,570,500
February	-22.29	1,008,900*	1,298,300	1,019,300 - 1,577,300

*Significantly different from forecasted value with $p \leq .05$.

through 1978 period would continue, most of the forecasted values were larger than the actual values, which did not follow the upward trend. The deviations of the actual values from the forecasts indicated, therefore, that there apparently was a change in slope starting at the beginning of 1979, with the upward trend identified during the baseline period no longer evident.

Two months deviate from the overall pattern of lower than expected wine distribution in 1979 and early 1980. Wine distribution in October and November 1979 was 24 and 21 percent higher than forecasted, respectively. Except for these two months, wine distribution after the drinking age was raised was consistently lower than predicted using the 10 year baseline period.

5.4 Discussion

In summary, packaged beer distribution for January 1979 through February 1980 was clearly lower than expected, and draught beer was clearly higher than expected given the trends evident over the previous 10 years. Wine distribution fell somewhat for most of 1979, but rebounded late in the year. A portion of the decrease in packaged beer sales may have been due to the raised drinking age, but other factors were also present. A main confounding factor was the ban on non-returnable beverage containers in Michigan, which was implemented in the same month the drinking age was raised. The resulting increase in packaged beer prices (Michigan State Legislature, 1979) may have caused a shift to the less expensive draught beer by those who consumed bottled beer in public drinking establishments. (4) The increased price of bottled beer and the

inconvenience of returnable containers may have caused consumers residing near bordering states with non-returnable containers to purchase their packaged beer across state lines.

The substantially increased sales of draught beer was contrary to the hypothesis that the raised drinking age would reduce on-premise draught beer consumption by reducing the population of legal drinkers. It is important to note, however, that only a small proportion of total draught beer distribution represents consumption by 18-20 year old drinkers. The increased distribution volumes may reflect changes in consumption among drinkers 21 and over. A plausible explanation of the increased draught beer sales is that the economic recession in Michigan increased draught beer consumption among unemployed workers. Another consideration is that draught beer is not solely consumed on-premise. Part of the increased draught beer sales in 1979 may be a result of an increased number of "kegger" parties among 18-20 year olds, where a legal drinker purchases a keg of draught beer for consumption off premise at a party attended by underage drinkers.

Finally, the lower than expected distribution of wine for most of 1979 could be interpreted as a result of the raised drinking age. However, the high wine distribution figures for October and November 1979 complicate such an interpretation.

One can only speculate as to the causal structure underlying the observed changes in beverage alcohol distribution in Michigan in 1979 and early 1980. Without age specific consumption data the effect of the raised drinking age could not be unambiguously determined. Furthermore, detailed information on the drinking practices of various subpopulations

within the state as identified by stratification variables such as income level and employment status is necessary for an assessment of the relative influence of economic conditions, price changes in various beverage categories, and the legal drinking age, on individual drinking patterns.

Notes to Chapter 5.0

1. The legal drinking age in Massachusetts was lowered from 21 to 18 in 1973.

2. See McCleary and Hay (1980:222-224) for a discussion of the limitations of using univariate forecasts for an assessment of the effects of exogenous factors on time-series measures.

3. The percent change figures represent the difference of the actual value for a particular month from the forecasted value expressed as a percentage.

4. In public drinking establishments in Michigan, draught beer is consistently the lowest priced alcoholic beverage (Douglass et al., 1980).

6.0 SUMMARY AND CONCLUSIONS

The present study has investigated a complicated relationship between a legal change and a major public health problem. Discussed below are (A) the findings and conclusions of this research, (B) recommendations for further research, and (C) implications and recommendations for public health policy.

6.1 Summary of Findings

The most important hypothesis of this research was that the raised legal minimum drinking age (from 18 to 21) caused a reduction in alcohol-related motor vehicle crash involvement among drivers aged 18-20 (see Section 2.4). The data on crash involvement in Michigan clearly supported this hypothesis. Controlling for trends, seasonality, and other patterns in the frequency of police-reported "had been drinking" (HBD) crash involvement among 18-20 year old drivers, a reduction of 31 percent occurred in the first 12 months after the drinking age was raised from 18 to 21 in December of 1978.

To control for potential unreliability in police-reported alcohol-involvement, a "three factor surrogate" (3FS) measure of alcohol-related crash involvement was also used. Analyses of late-night, single-vehicle crashes with a male driver, of which a majority have been consistently identified as involving a drinking driver, revealed a statistically significant reduction of 18 percent among drivers aged 18-20 after the higher legal drinking age was implemented. In terms of the

actual reduction in the frequency of collision involvement, an estimated reduction of 138 alcohol-related crash involvements per month occurred after the drinking age was raised. Over the first 12 months after implementation of the higher drinking age in Michigan, therefore, an estimated 1650 fewer alcohol-related crash involvements occurred than would have been expected, given the trends evident during the 1972 through 1978 baseline period.

Analyses of non-alcohol-related crash involvement among 18-20 year olds identified a non-significant 7 percent drop in 1979. Since the significant crash reductions for 18-20 year olds were not found for general non-alcohol-related crashes, one cannot attribute the observed reduction in HBD and 3FS crash involvement to increased fuel prices, economic recession, and other such confounding factors. If one deducts the (non-significant) 7 percent reduction in "had not been drinking" (HNBD) crash involvement from the more conservative drinking age impact estimated, i.e. an 18 percent reduction in 3FS crash involvement, an 11 percent reduction in alcohol-related crash involvement remains, even after the (non-significant) effects of other factors are subtracted. It is clear that general reductions in crash involvement due to potential confounding factors cannot explain away the substantial reduction in alcohol-related crash involvement among drivers aged 18-20 after the drinking age was raised.

In addition to analyses of all alcohol-related crash involvement (including property damage, injury, and fatal collisions), separate analyses of fatal crash involvement were conducted. Preliminary analyses did not reveal substantial changes in 3FS fatal crash involvement that

could reliably be attributed to the raised drinking age. See Section 4.3 for a discussion of the limitations on separate analyses of fatalities.

The second hypothesis was that lowering the legal drinking age from 21 to 18 in 1972 caused an increase in alcohol-related crash involvement. Inconsistencies in the recording of non-fatal crash involvement in several Michigan jurisdictions prior to 1972 precluded the use of those data for an evaluation of the lowered drinking age in the present study. Accurate counts of fatal crash involvement were available for the 1968 through 1979 period. Examination of the time-series plots of fatal crash involvement provided some evidence that the lowered drinking age was associated with increased alcohol-related fatal crash frequencies, but the small monthly count of age-specific fatalities precluded any reliable conclusions. The best estimate of the effect of the lowered drinking age on alcohol-related crash involvement remains that of Douglass and Freedman (1977). They analyzed a set of Michigan jurisdictions with complete accident reporting over the 1963 through 1975 period, using a time-series design. The results revealed a 17 percent ($p<.06$) increase in total (non-fatal and fatal) alcohol-related crash involvement (as measured by the BFS indicator) among drivers aged 18-20 associated with the lowered drinking age. Since total crash involvement among 18-20 year old drivers was up only 3 percent, and since alcohol-related crash involvement of drivers over 21 was up only 3 percent, the 17 percent increase in alcohol-related crash involvement among young drivers was attributed to the raised drinking age.

Hypotheses three through five stated that the raised and lowered drinking age would cause changes in alcohol-related crash involvement of

drivers aged 16-17, although with a smaller magnitude of impact than the focal 18-20 age group. The results of the current research provided some support for these hypotheses. First, with regard to the effect of the raised drinking age, a statistically significant 15 percent reduction in 3FS crash involvement occurred at the time the drinking age was raised. An estimated reduction of 47 crash involvements per month was associated with the raised drinking age. The results were more ambiguous than the results for the 18-20 age group, however, since only a small, non-statistically significant reduction in "had been drinking" crash involvement was identified for drivers aged 16-17.

The exact reasons for this discrepancy are unknown. However, the three-factor-surrogate is generally considered the more reliable measure, because the subjective "had been drinking" measure may be influenced by numerous uncontrolled influences, particularly for underage youth. As a result, it is cautiously concluded that alcohol-related crashes among 16-17 year old drivers did decrease subsequent to the higher legal drinking age. Since "had not been drinking" crash involvement also experienced a significant 7 percent decrease, part of the 15 percent decrease in alcohol-related (i.e., 3FS) crash involvement may have been caused by factors unrelated to the drinking age. The remaining 8 percent (i.e., 15 less 7) decrease in 3FS crash involvement can be considered the drinking age effect, supporting the hypothesis that the raised drinking age has an effect on drivers aged 16-17 that is smaller in magnitude than the effect on drivers aged 18-20.

With regard to the effect of the lowered drinking age on drivers aged 16-17, examination of the frequency of fatal 3FS crash involvement