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Long Term Impacts of California's Graduated Licensing Law of 1998

Douglas Cooper
David Gillen

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The contents of this report reflect the views of the authors who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the State of California. This report does not constitute a standard, specification, or regulation.

Final Report for Task Order 5100

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**LONG TERM IMPACTS OF CALIFORNIA'S GRADUATED LICENSING
LAW OF 1998**

An assessment by the Institute of Transportation Studies at UC Berkeley
of the long term effects of the law on fatal and injury crashes of 16 year-old drivers

Douglas Cooper

David Gillen

Frank Atkins

March, 2005



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EXECUTIVE SUMMARY

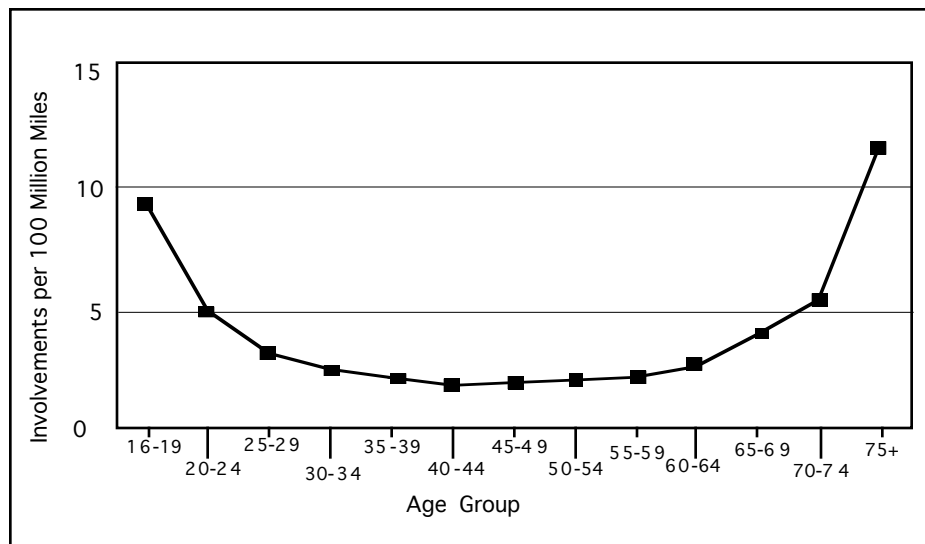
In July 1998 California changed its graduated driver licensing laws (GDL) for new drivers under the age of 18 to include restrictions on hours of driving, carrying teen-age passengers, and requiring more adult supervised driving practice. With fatal and injury crash data from California's Statewide Integrated Traffic Records System, this study, sponsored by Caltrans, used standard regression analysis as well as the Bai-Perron stochastic multiple structural break model to determine the effect of the law on teen-age passengers and crash rates of 16 year-old drivers. We found that in the four and one-half years following implementation of the new law, crashes caused by 16 year-old drivers decreased by 11% and the average number of teen-age passengers carried by 16 year-olds decreased by approximately 31%. The combination of these two decreases resulted in the saving of 29 lives and the prevention of 2,632 injuries.

To test the specific effect of the restrictions on driving between midnight and 5 AM, regression analysis was performed on the quarterly percentage of curfew crashes for 16 year-old drivers. Quarterly data was used due to the relatively small number of curfew crashes. The percentage of curfew crashes have been in a nearly significant long term down trend since 1996. There was a small, non-significant lessening of the long-term downward trend at the time of the implementation of the new law. The new law does not appear to have had a material effect on the percentage of driving done by 16 year-olds during curfew hours. This percentage was in a downtrend prior to the law and continued after the law took effect.

1.0 INTRODUCTION

It is well established that drivers at both ends of the age spectrum present a driving risk to both themselves and others that is disproportionate to their numbers on the road (e.g., Massie et al., 1995; Li et al., 2003). As can be seen in Figure 1.1 below, the risk of fatal crash involvement varies dramatically with the age of the driver, with the youngest age group, drivers 16 to 19, having a rate of 9.2 involvements per 100 million VMT, and the oldest group, drivers aged 75 and over, with a rate of 11.5 (Massie et al. 1995). It should be noted, however, that older drivers, being more “fragile” than younger drivers, will be over-represented in fatal and injury crashes.

Figure 1.1 Fatal Involvements per 100 Million Miles



Source: Massie et al., 1995

Nationally, motor vehicle crashes are the leading cause of death for drivers aged 16 to 20. In California, teen drivers are over-represented in every category of traffic crashes. While they make up only 4% of all licensed drivers in the state, teens are responsible for 15% of the state's fatal and injury crashes. Sixteen year-olds are six times more likely to cause a fatal and injury crash and nine times more likely to be involved in single vehicle crashes than adult drivers age 25 to 54 (Cooper et al., 2002).

In order to take advantage of the fact that teen driver crash risk decreases dramatically with experience (Mayhew et al., 2003; McCartt et al., 2003; Ferguson, 1996; Simpson and Mayhew, 1992; Mayhew and Simpson 1990), most states have implemented at least one element of

graduated driver licensing (GDL), and, since 1997, thirty-seven states have introduced three-stage GDL systems (Foss and Goodwin, 2003) which allow teens to gain experience under lower risk conditions. GDL is summarized by IIHS (2003) as “a system for phasing in on-road driving that allows beginners to obtain their initial experience under lower risk conditions. The ideal program has three stages: a supervised learner’s period, an intermediate license (once the driving test is passed) that limits unsupervised driving in high-risk situations, and a full-privilege driver’s license available after completion of the first two stages. Beginners must remain in each of the first two stages for set minimum time periods.” It is during the intermediate stage that teen drivers’ exposure to the two highest risk conditions, nighttime driving and carrying teenage passengers (Chen et al., 2000; Preusser et al., 1998; Cooper et al., 2002) is restricted.

1.1 California's Graduated Licensing Law

While a form of graduated licensing has existed in California since 1983, a new, more stringent law took effect on July 1, 1998. In addition to conditions and restrictions already existing under the old law, the main provisions of the new law require that:

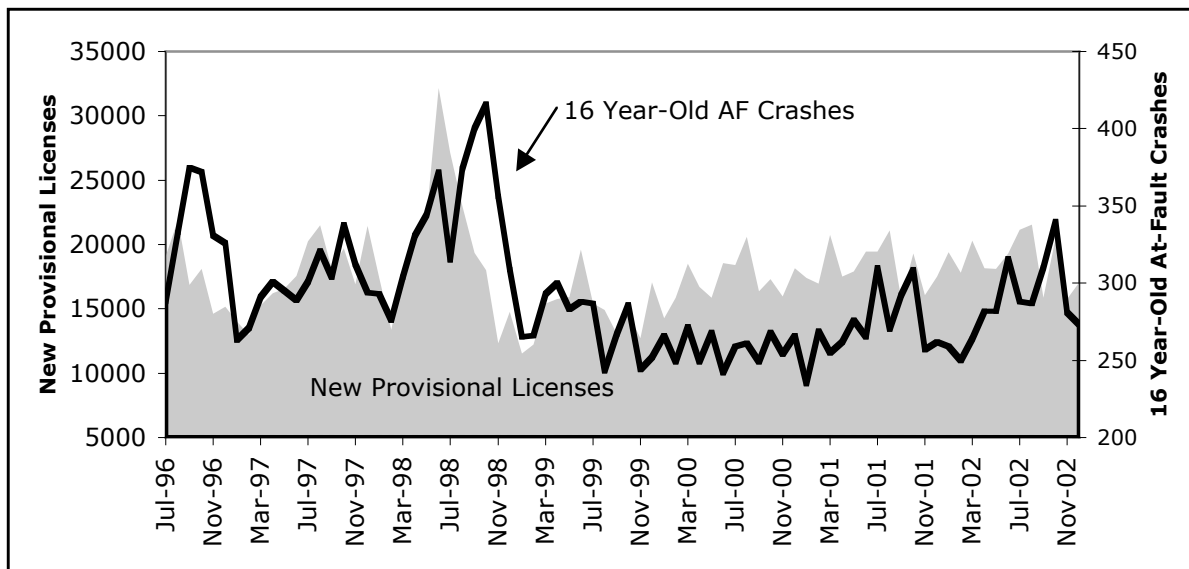
- Teens under 18 years of age hold their instructional permit for six months before they can take a drive test for their provisional license. Previously the law specified 30 days.
- During the instructional permit period the prospective driver must have 50 hours of adult-supervised driving practice (an increase of 20 hours), 10 of which must be at night.
- Provisional license holders cannot drive between midnight and 5 a.m. for the first year they hold the license unless supervised by a parent, guardian, driving instructor or adult age 25 or older.
- Provisional license holders may not transport passengers under 20 years of age for the first six months, unless supervised by a parent, guardian, driving instructor or adult age 25 or older.

The announcement of the pending law created a change in behavior of 16 year olds who had planned on obtaining a license. Specifically, there was a rush to become licensed prior to July 1 in order to avoid being subject to the constraints of the new law. Figure 1.2 clearly shows the large increase in the number of new provisional licenses being issued. The shift in behavior created, in

effect, a disequilibrium in the number of 16-year old licensed drivers which previously had had a fairly steady state of about 100,000 at any one time.

The rush to get licensed led to a large increase in the number of young drivers on the road for the period May 1998 through February 1999 which, in turn, led to an increase in crashes. In the following months there was a reduction in the number of new 16 year-old drivers because people had shifted their decision to obtain a license forward in time. As there were now fewer young drivers on the road, the number of crashes fell. This pattern can clearly be seen in Figure 1.2.

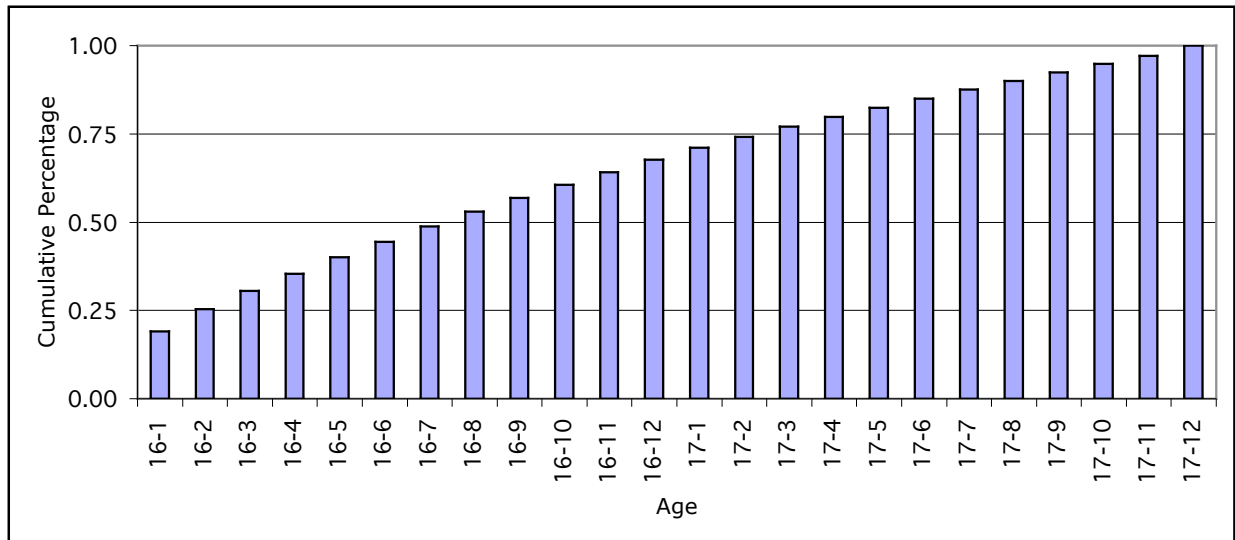
Figure 1.2: New Provisional Licenses & 16 Year-Old At-Fault Crashes



1.2 Age Group

The focus of this report will be 16 year-old drivers. The reasons for this are twofold. First, at least theoretically, the last drivers who could still be subject to the old law will not pass out of the system (turn 18) until June 2002. Second, since the key restrictions of the new law apply for a limited time (six months for passengers and one year for curfew) and since approximately 45% of teenagers acquire their license by age 16 1/2 (Figure 1.3), a large segment of the 17 year-old driver population would not be subject to the laws restrictions.

Figure 1.3: Cumulative Percentage of Age At First License 7/99-12/02



1.3 Purpose and Format

The raison d'être of GDL is to reduce crashes and save lives. California's law has now been in effect for six years. The short term effects have been encouraging, with a reductions in crashes per licensed driver as well as the number of passengers being carried in crash involved cars (Cooper et al., 2002). California crash data is now available through December, 2002 which gives us four and a half years of post-law data. The purpose of this study is to determine if the favorable short term results have continued. This will be done by looking at the law's effect on the crash-rate of 16 year-old drivers, the carrying of passengers by 16 year-olds, and curfew crashes.

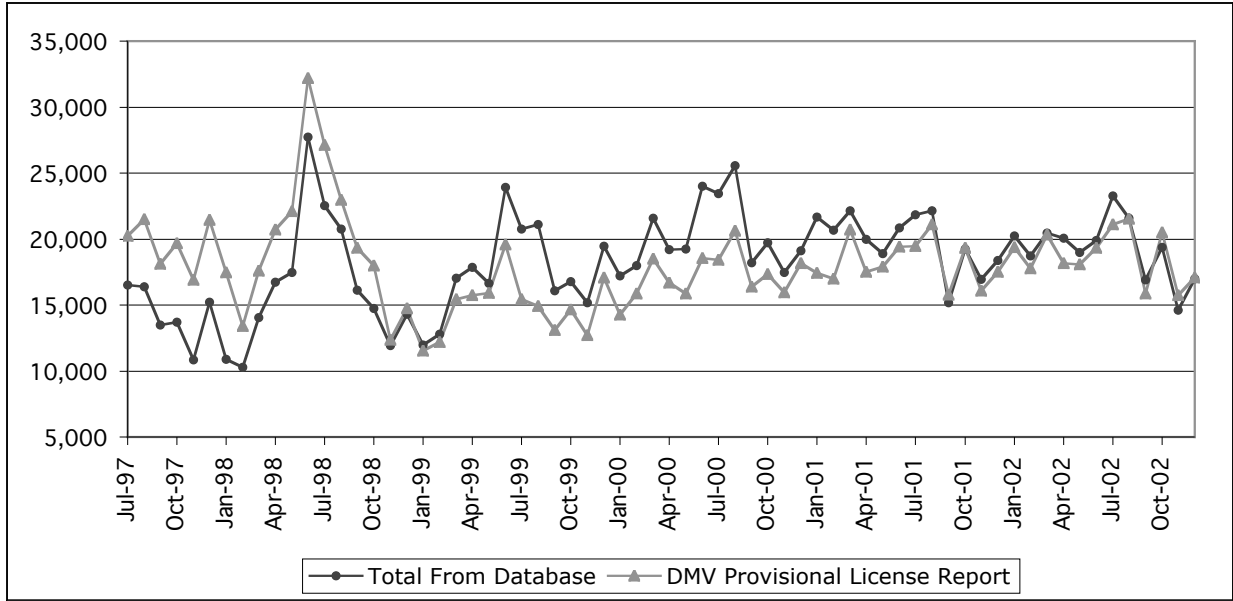
1.4 Data

Crash Data: Except where noted, all crash and passenger data included in this report is obtained from the Statewide Integrated Traffic Records System (SWITRS). SWITRS processes all reported fatal and injury collisions which occur on California's state highways and all other roadways, excluding private property. Since property damage only (PDO) crashes are not consistently reported by the various agencies throughout the state they are considered indicators of the volume of traffic collisions only and are not exact statistics (CHP 1999). For this reason, all crashes used for this study are fatal or injury crashes. Additionally, only drivers of cars, vans, or light trucks and their passengers are included.

Driver License Data: The Department of Motor Vehicles maintains a database of all licensed drivers in the state which includes type of licenses and ID cards held as well as license acquisition/change dates. Determining the actual number of licensed drivers from this database, however, can be quite a challenge. Each time a license or ID card is acquired, changed or replaced, the date is added to a person's record. Since there is only room for six such entries, the seventh and subsequent dates are written over earlier entries. Additionally, there is no way to associate a specific license action with a specific date. Thus, if a person obtained a drivers license, had it suspended, obtained an ID card, then was issued a new driver's license, there is no way to tell which date in the record pertains to which event.

The data supplied by the DMV consists of all persons born after July 1, 1979 who hold an I.D card, learner's permit, provisional license, or full license, for a total of 3.9 million records. Since a person must be at least 16 in order to be issued a provisional license, the earliest date which made the age at issue 16 or greater was assumed to be the correct date. Since this is bound to produce some degree of error in the number of licensees, the resulting total monthly issuance of provisional licenses derived from the database was compared to the published monthly total of provisional licenses provided by the DMV. This monthly total is considered accurate in that it is automatically created as it occurs, and requires no search of past records. The comparison is shown in Figure 1.4.

Figure 1.4: Comparison of Database and DMV Report of New Provisional Licenses



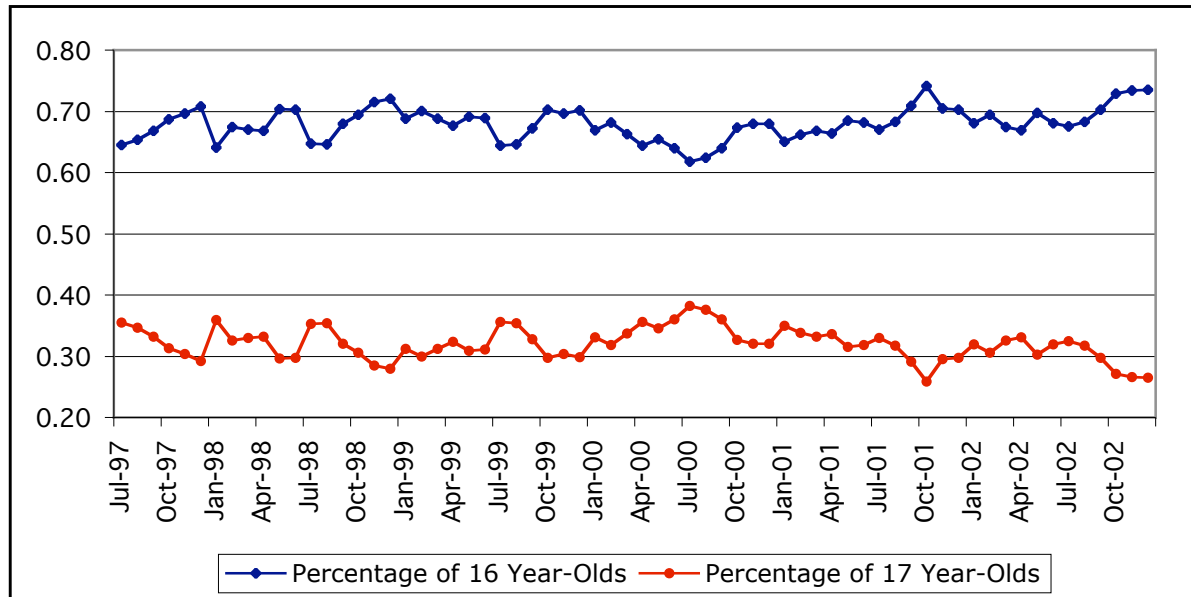
As can be seen, the two lines are very similar in shape. Given this similarity as well as the inherent accuracy of the DMV’s monthly report, we felt that it was reasonable to adjust the database numbers to that of the DMV. If this procedure introduces an error into our analysis, it will work against the case of a positive effect of the new law because this adjustment results in more licensed drivers in the “before” period (and therefore fewer crashes per licensed driver) and fewer licensed drivers in the “after” period, resulting in more crashes per licensed driver. In making the adjustments to our totals, the original percentage allocations by month and age at first license were maintained.

Due to the fact that the database supplied to us begins with people born on or after July 1, 1979, we only have complete data for 17 year-olds starting in July, 1997, or one year prior to the new law going into effect. If we want to go back further than that (since we have accident data going back to January 1996) we will have to estimate the number of 16 and 17 year-old licensees using known percentages established earlier and the monthly total number of provisional licenses which we have going back as far as 1989.

As shown below the percentage of total new licenses made up by each age group is quite consistent over time. Additionally, in a regression, almost all of the months are statistically significant which means that there is a systematic variation between specific months. Therefore,

twelve monthly averages were computed and these averages applied to the DMV monthly provisional license report to come up with estimated July 1996 through June 1997 totals for 16 and 17 year-olds.

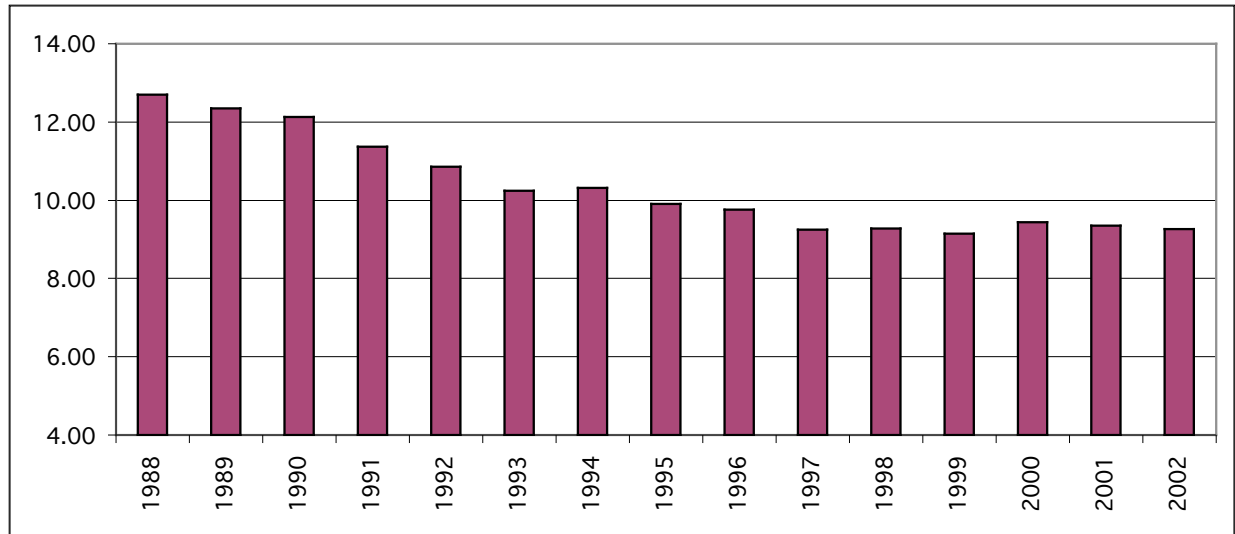
Figure 1.5: Percentage of New Provisional Licenses held by 16 and 17 Year-Olds



2.0 CRASH RATE

From 1988 through 1997, the overall fatal and injury crash rate in California declined from 12.69 to 9.26 per 1,000 licensed drivers, fueled, at least in part, by safer cars and improved infrastructure. Time-series analysis of the data shows a highly significant ($p=0.0$) change in the slope of the trend line in 1997 and since that time the crash rate has varied between 9.14 and 9.44 crashes per 1,000 licensed drivers (Figure 2.1).

Figure 2.1 Total Fatal and Injury Crashes Per 1,000 Licensed Drivers in California



Source: California Highway Patrol

For this study, the challenge was to separate the effect of the new law on 16 year-old drivers from the long term trend in the overall crash rate as well as the disequilibrium created by the change in licensing behavior brought about by the change in the law. While several metrics were considered, including crashes per unit population and involvement ratio (which considers the relative crash risk of various age groups), it was decided that crashes per licensed 16 year-old driver would be the most sensitive to any changes brought about by the new law.

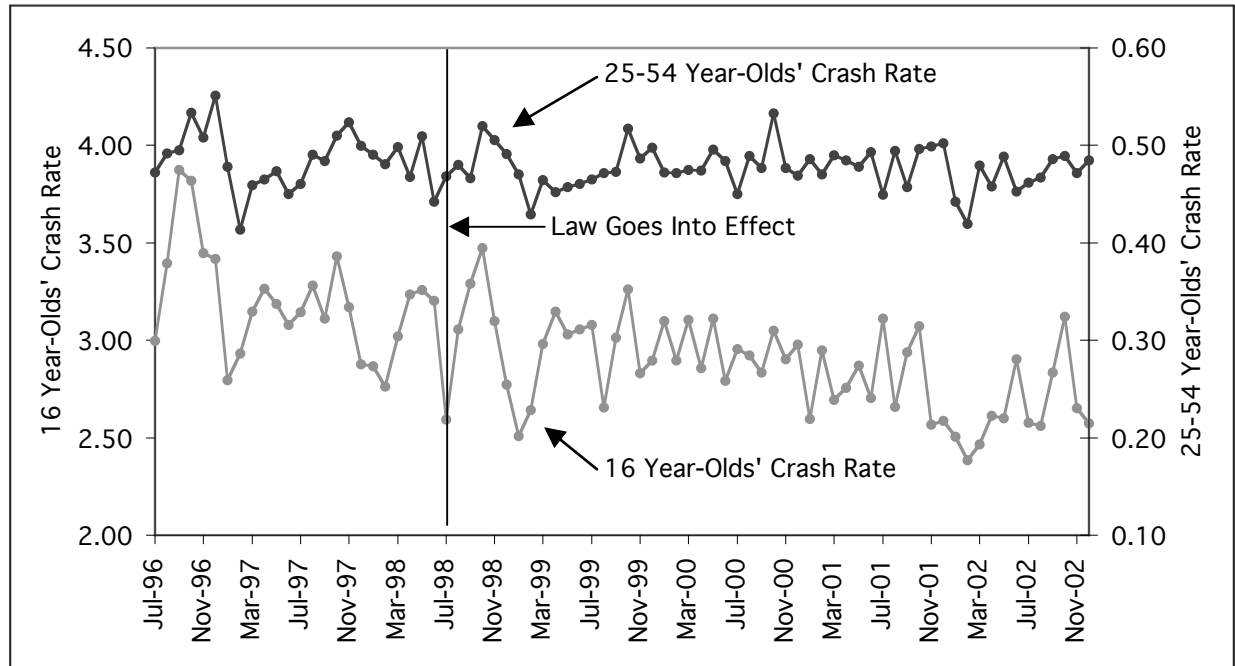
2.1 Methodology

While direct comparisons between age groups on a “per licensed driver” basis can be misleading, due to differences in exposure, this type of data can be used within a specific age group to look for changes over time. These changes over time within an age-group can then be compared to changes over time of other age groups. With this in mind, two types of analysis were performed: first, a standard time-series analysis of crashes per licensed 16 year-old driver from July 1996 through December 2002 was compared to a similar analysis of the crash rate per licensed 25-54 year-old was also examined and compared. The second analysis was carried out using a new econometric technique developed by Bai and Perron (2002) that provides a means of distinguishing different regimes of behavior.

2.2 Crash Rate Time-Series Results

Using the estimated and actual number of licensed 16 year-old drivers and the number of 16 year-old at-fault crashes from the SWITRS database, the number of crashes per 1,000 licensed 16 year-olds was calculated and plotted as shown in Figure 2.2.

Figure 2.2: Number Of Crashes per 1,000 Sixteen Year-Old Licensed Drivers



Time-series analysis of the data for the period July 1996 through December 2002 for both 16 year-olds and 25-54 year-olds shows a significant downward time trend ($p=0.0$ and $p=.069$, respectively).

Since there are no significant changes in either age group's crash rate after July 1998, the only way to measure the effect of the law was to use the estimated equations to compare the rate of change over time for the two age groups. Time is the only continuous variable in the regression while all other variables are indicator variables taking on a value of 0 or 1, which serve to shift the estimated equation up or down depending on the sign of the parameter.

Elasticities are defined as the ratio of the incremental percentage change in one variable (in this case crash rates) with respect to an incremental percentage change in another variable (time) and are generally calculated to show the degree of responsiveness of a dependent variable to changes

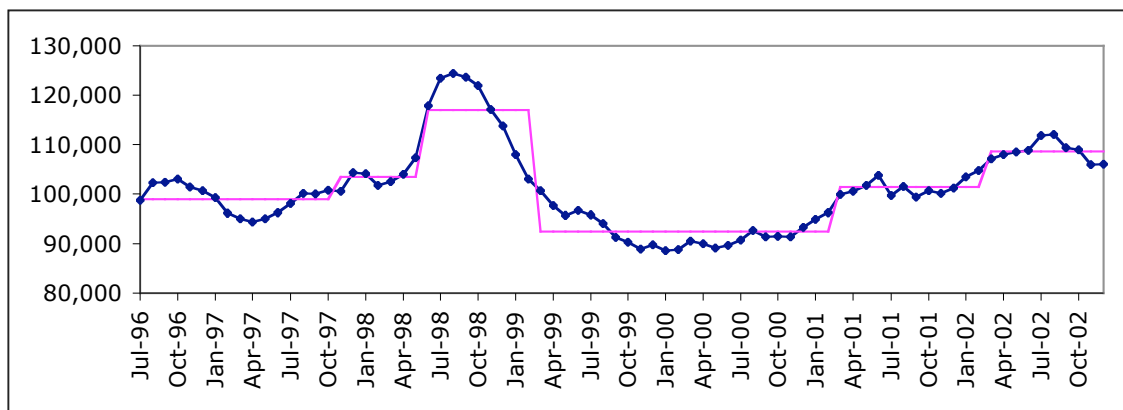
in the independent variable. Our time elasticities measure the percentage change in crash rates with a particular percentage change in the time period. While time cannot be manipulated, the elasticity still serves as an indicator of how quickly things are changing according to the length of time included in the study. In our case the monthly data cover 78 periods, or 6.5 years.

For the crash rates for 16 year olds, the elasticity of crash rates with respect to time is -0.118 while for the adult (ages 25 through 54) crash rates it is -0.017 . There is a sizable difference between the two. The former would be interpreted as a one percent increase in time would lead to a 0.12 percent reduction in crash rates for 16 year old drivers, simply as a trend. The interpretation for adult drivers would be a one percent increase in time would lead to a .02 percent decline in accident rates. Thus, over time, adult drivers crash rate reduction is falling at a sixth the rate of decline in crash rates for 16 year olds. This difference must be explained by some factor other than time, the difference is simply too large. Both groups drive approximately the same stock of vehicles and operate within the same stock of infrastructure.

2.3 Crash Rate Bai-Perron Results

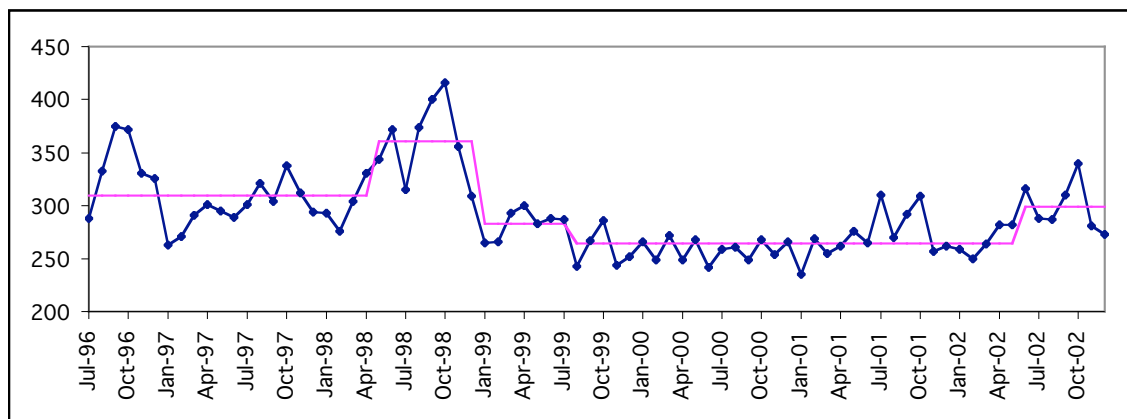
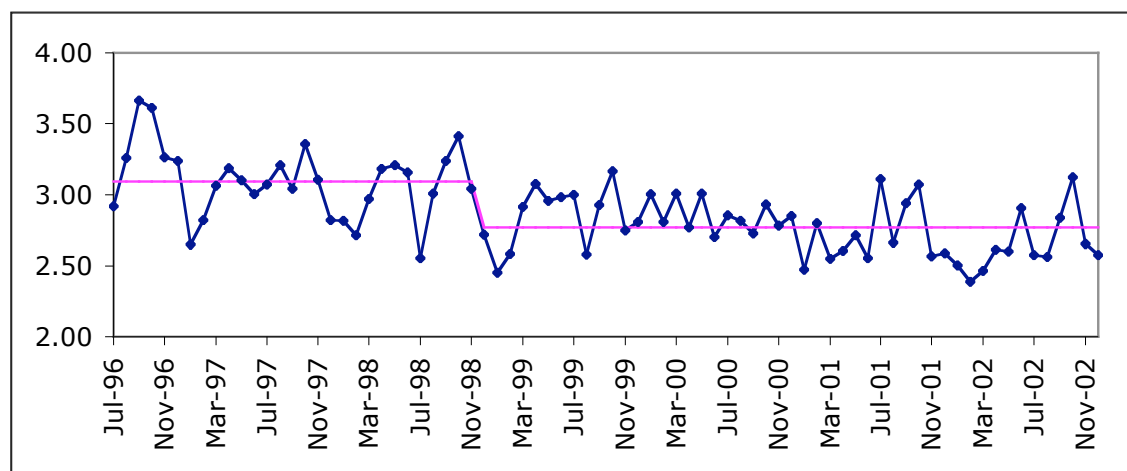
The key difficulty in undertaking the analysis is to be able to distinguish equilibrium and disequilibrium periods in the data and the Bai-Perron technique allows us to do this. Failure to distinguish the period of adjustment from the trend will lead to errors in the calculation of the impact of the new law. There are three general periods to be considered, the period prior to the change in the law, the period of adjustment after the law is announced and comes into effect, and the period of the new equilibrium when all adjustments to the new law have been internalized.

In our case the regimes are: the law is announced to go into effect at a future date, people rush to get license before law goes into effect, after law goes into effect there are fewer than normal applicants because people moved their decision ahead, over time we move back into equilibrium again. There are three to four regimes in this explanation.

Figure 2.3: Number of Drivers and At-Fault Crashes

As can be seen in Figure 2.3, the number of drivers begins to increase at some point in mid 1997. The BP technique picks up the first break in October, 1997, when the mean number of drivers increases from 98,977 to 103,489. This increase continues through 1998, with another mean increase detected in May, 1998. Notice that this increase peaks at some point in late 1998, early, 1999. It appears that approximately 5,000 sixteen year olds shifted their decisions to become drivers early, in anticipation of the change in legislation. The technique picks the peak at February, 1999.

At the same time that the number of drivers is increasing, the number of at-fault accidents is also increasing throughout 1998 (Figure 2.4). Between July, 1996 and April, 1998, the mean number of at fault accidents is 309.5, and this increases to 360.75 over the period May, 1998 to December, 1998. The important point to note here is that, throughout the period of the increase in the number of drivers, there is a proportionate increase in the number of accidents, and, therefore, during this period, the mean at fault accident rate remains statistically constant at 3.09 (Figure 2.5). Thus, for this period, the number of accidents is following the number of drivers in an equilibrium regime. This is the equilibrium regime that is in force prior to the enactment of the legislation.

Figure 2.4: At-Fault Crashes By 16 Year-Old Drivers**Figure 2.5: At-Fault Crash Rate Of 16 Year-Old Drivers**

Beginning in late 1998 or early 1999, the number of drivers begins to decrease. Between March 1999 and February, 2001 the mean number of drivers decrease to 97,495. At the same time, the number of at fault accidents begins to decrease. Between January, 1999 and July, 1999, the mean number of at fault accidents decreases to 283.14, and between August, 1999 and May, 2002, there is a further decrease to 264.28. However, the number of at fault accidents is falling proportionally more than the number of drivers, as the mean at fault accident rate fall to 2.76. Thus, once again, the number of accidents is responding to the number of drivers, but now there is a regime shift, so that the number of accidents per driver has decreased.

Notice that there is a confirmation of this new regime towards the end of the sample. In February, 2002, the mean number of drivers increases to 108,638. This would be consistent with the last phase of driver adjustment in response to the legislation. First, the number of drivers increased in anticipation of the legislation. Then there were less drivers, as an unusual bulge went

through the system. Finally, the number of drivers increases to reflect the last stage of adjustment. During this final stage of adjustment in the number of drivers, the number of at-fault accidents increases. However, this increase obeys the new relationship between drivers and accidents, as the accident rate remains constant at 2.76.

We are now in a position to estimate how many lives the law has saved and how many severe and minor injuries have been prevented by reducing the crash rate. We do this by simulating the number of crashes that would have occurred had the law not been put in place and comparing it to the actual result. The difference in crashes is then linked to the average number of people in crash involved cars (see the section on passengers later in this report for the derivation of this average) and the typical injury pattern of crash involved people.

The simulation involved four steps. First, we had to simulate what the distribution of drivers over time would have been had no change in the law occurred (i.e., with no rush to obtain a license and no change in driving habits). This was accomplished by smoothing the “Number of Licensed Drivers” curve over the period of the study. Once we have the ‘normal’ number of drivers and their distribution over time we can simulate the number of crashes utilizing the pre-law crash rate found using the Bai-Perron analysis (3.09 at-fault crashes per 1,000 licensed 16 year-olds) that would have occurred in the absence of the law. Next, since we know the average number of passengers in cars driven by 16 year-olds prior to the law, we can calculate how many people avoided being involved in crashes. Finally, using the percentage of victims who fall into each crash category determined by looking at all crash-involved cars driven by 16 year-olds, we can calculate the number of deaths and injuries avoided. The results of these calculations showed 2,109 crashes avoided resulting in 10 lives saved and 46 severe, 359 visible, and 555 “complaint of pain” injuries prevented.

3.0 Passengers

During the first six months of a provisional license, it is illegal to carry passengers under 20 years of age unless "accompanied and supervised by a parent, guardian, licensed driver 25 years of age or older, or a licensed or certified driving instructor"(California Vehicle Code).

This restriction on passengers has the potential to reduce fatalities and injuries in two ways. First, there is ample evidence to show that the presence of teenage passengers increases the risk of a crash ((Chen et al., 2000; Preusser et al., 1998; Doherty et al., 1998; Cooper and Gillen, 2005). Second, if a crash occurs, fewer people in the car means fewer potential victims.

The first part of our analysis will show that carrying teen passengers continues to increase the risk of a crash. In the second passenger section, we will show that the new law continues to reduce the number of teen passengers, saving lives and preventing injuries.

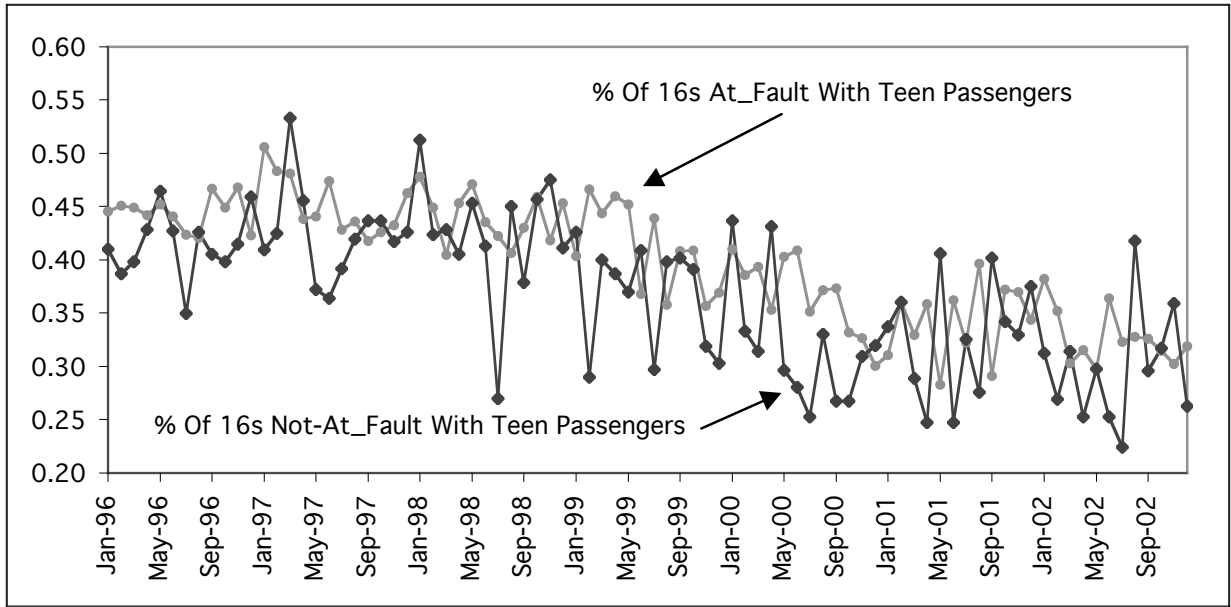
In the second part of the analysis, 16 year-old not-at-fault crash victims will be used as a surrogate for a random sample of 16 year-old drivers on the road. This approach is supported by numerous studies utilizing a technique called “induced exposure” which is based on the premise that the “innocent victims” of crashes (i.e., the drivers determined not to have been at-fault in a crash) represent a random sample of the drivers on the road (e.g., Massie et al., 1995; Lyles et al., 1991).

3.1 Effect of Carrying Passengers

If carrying teenage passengers has an effect on the crash rate of 16 year-old drivers we would expect to see 16 year-olds who cause crashes to be carrying more passengers than those who are found to be not-at-fault in crashes.. To see if this is the case, the percentage of 16 year-olds who were at-fault in a crash and were carrying at least one teenage passenger was compared to the percentage of 16 year-olds who were not-at-fault in a crash and were carrying at least one teenage passenger. To be counted in these comparisons, drivers must be carrying ONLY passengers of the correct age or be carrying no passengers. For example, a car carrying a 17 year-old and a 20 year-old passenger would not be used.

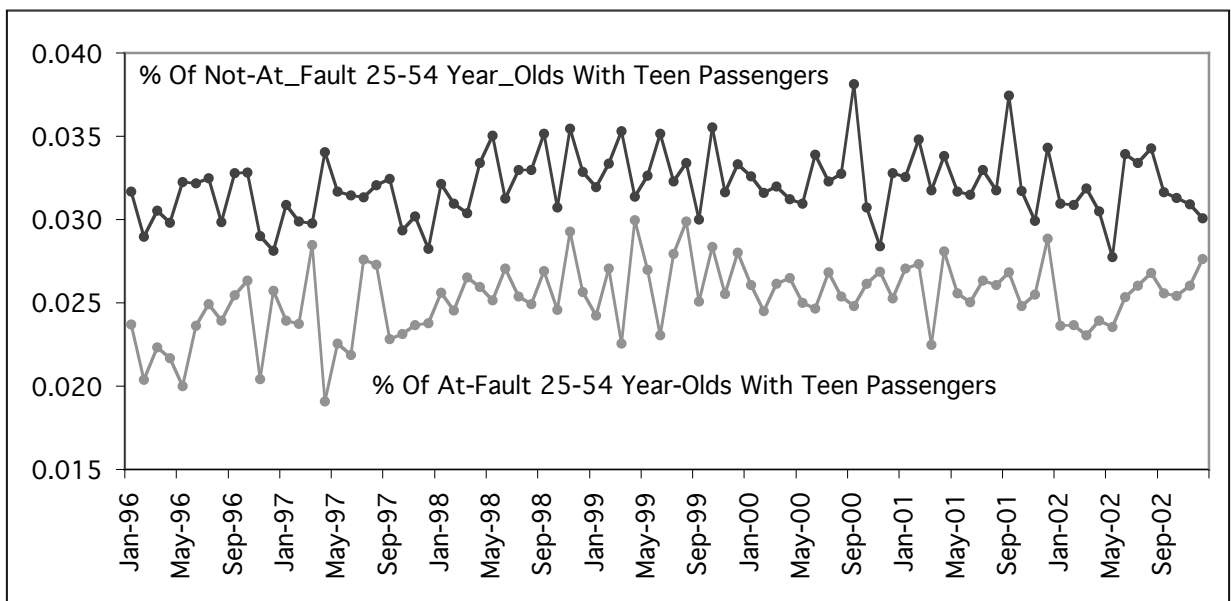
A plot of the two crash percentages are shown in Figure 3.1. A two-sample t-test assuming unequal variances was performed and the difference was highly significant ($p = 0.0$)

Figure 3.1: Percentage Of 16 Year-Old Drivers In Crashes With Teen Passengers



The same test was carried out for drivers aged 25-54 years-old. The results again were highly significant except in this case it was in the opposite direction ($p = 0$). That is, while teenage passengers are a contributing factor in crashes involving teen drivers, they appear to lead to safer driving in older adults. The graphical comparison of the percentage of at-fault and not-at-fault 25 to 54 year-old drivers carrying teenage passengers is shown in Figure 3.2.

Figure 3.2: Percentage Of 25-54 Year-Old Drivers In Crashes With Teen Passengers

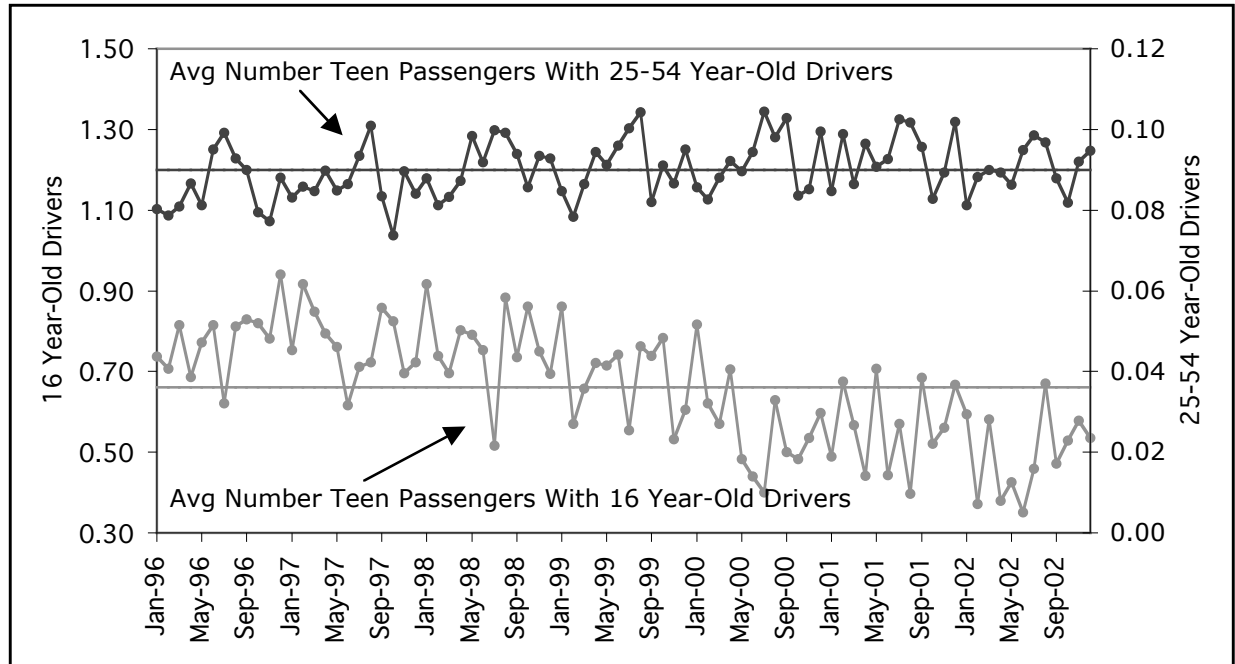


3.2 Effect of The New Law on Teenage Passengers

It is apparent in Figure 3.1, which shows the percentage of 16 year-old drivers in crashes with teen passengers, that the slope of both the at-fault and not-at-fault lines begin to angle downward after the law went into effect in July 1998, indicating a decrease in the number of cars with teen passengers. The trend lines then appear to level out beginning in 2001 and remain at a lower level than in the pre-law years.

In order to test the significance and size of these changes as well as to determine the factors involved, a regression analysis was performed with the average number of passengers in all not-at-fault vehicles driven by 16 year-olds (Figure 3.3) as the dependent variable and Time, Law (a dummy variable equal to zero through June 1998 and equal to 1 thereafter), TimeLaw (an interaction term to see if the slope of the line changes after the law went into effect), Feb99, May00 (dummy variables equal to zero until those respective months and equal to one thereafter), and the months of the year as independent or explanatory variables. The variables for each month are designed to remove influences that are associated with the month and not with the change in the law. Not-at-fault crashes were chosen because, as discussed in the earlier, we feel they represent a random sample of the drivers of that age group on the road.

Figure 3.3: Average Number Of Teen Passengers In Not-At-Fault Cars Driven By 16 And 25-54 Year-Old Drivers



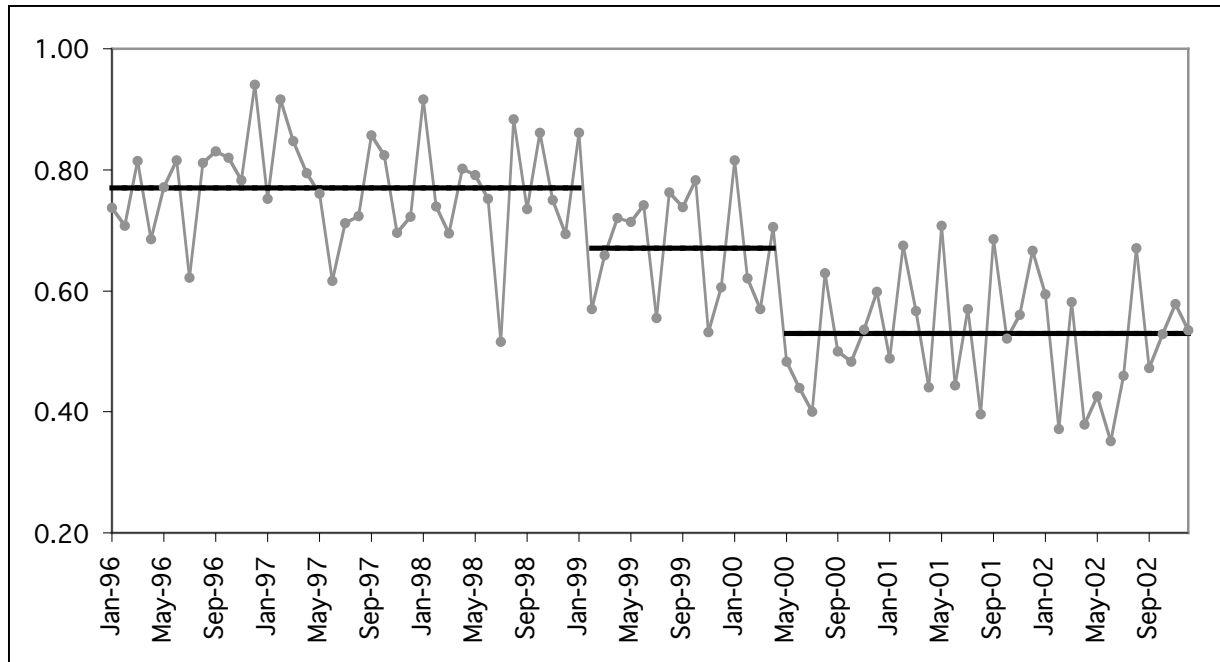
The regression was run several times, with different combinations of independent variables. The regression with the highest R-squared term is the one shown in Table 3.1. The independent variables Feb99 and May00 are highly significant ($p=0.0$). What the results tell us is that there are essentially three stages of the trend line: the period prior to the law, a transition period that begins several months after the law, and a third period, beginning approximately 1.8 years after the law. These levels are shown in Figure 3.4

Table 3.1: Regression Results For Average Number Of Teen Passengers Per Crash

Dependent Variable: AVGPAX16				
Method: Least Squares				
Sample(adjusted): 2 84				
Included observations: 83 after adjusting endpoints				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.800055	0.034442	23.22938	0
Feb 99	-0.095919	0.02105	-4.556609	0
May 00	-0.151395	0.021639	-6.996285	0
JAN	0.037041	0.054673	0.677508	0.5004
FEB	-0.048727	0.045755	-1.064954	0.2907
MAR	-0.02475	0.047722	-0.518636	0.6057
APR	-0.055455	0.047154	-1.176039	0.2437
MAY	-0.015464	0.0472	-0.327629	0.7442
JUN	-0.086076	0.047151	-1.825545	0.0723
JUL	-0.13293	0.0472	-2.816325	0.0064
AUG	0.016278	0.047051	0.345972	0.7304
SEP	0.007842	0.047602	0.164737	0.8696
OCT	0.008155	0.045488	0.179278	0.8583
NOV	-0.046909	0.053039	-0.884437	0.3796
AR(1)	-0.264518	0.116031	-2.279716	0.0258
R-squared	0.720834	Mean dependent var		0.658372
Adjusted R-squared	0.663359	S.D. dependent var		0.146671
S.E. of regression	0.0851	Akaike info criterion		-1.92787
Sum squared resid	0.492456	Schwarz criterion		-1.49073
Log likelihood	95.00648	F-statistic		12.54162
Durbin-Watson stat	2.016276	Prob(F-statistic)		0

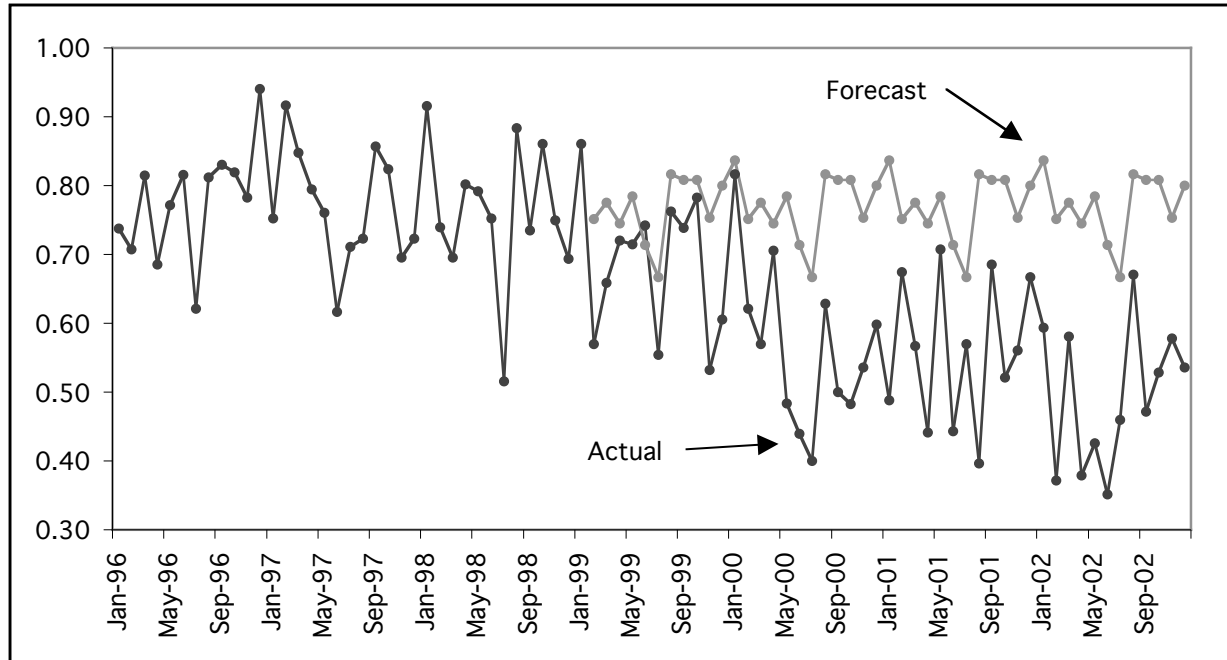
By way of comparison, a similar regression of the number of teenage passengers in crashes with drivers aged 25-54, yielded no statistically significant results. This is not surprising given the 25-54 year-old driver trend line shown in Figure 3.3.

Figure 3.4 Three Levels Of Average Number Of Teenage Passengers



Using the regression coefficients, the average number of teenage passengers was computed without the law related variables to forecast what the average number of teenage passengers would have been had the law not been passed. The forecast line as well as the line representing the actual average number of teen passengers per crash car in not-at-fault crashes are plotted in Figure 3.5. The area between the two lines represents those teens kept out of cars driven by 16 year-olds who were not-at-fault in crashes.

Figure 3.5: Actual and Forecast Average Number of Teen Passengers In Crashes Which Involved 16 Year-Old Drivers



By using the difference in the actual and forecast average number of teenage passengers of 16 year-old drivers involved in crashes as well as the average number of passengers who fall into each injury category when accompanying 16 year-old drivers , we are able to estimate the The number of lives saved and injuries prevented. These are shown in Table 3.2. We feel that this is a conservative estimate in that it was calculated assuming no change in the overall number of crashes. As demonstrated earlier, a decrease in the number of teenage passengers should lower the number of crashes which would result in even greater savings in terms of lives and injuries.

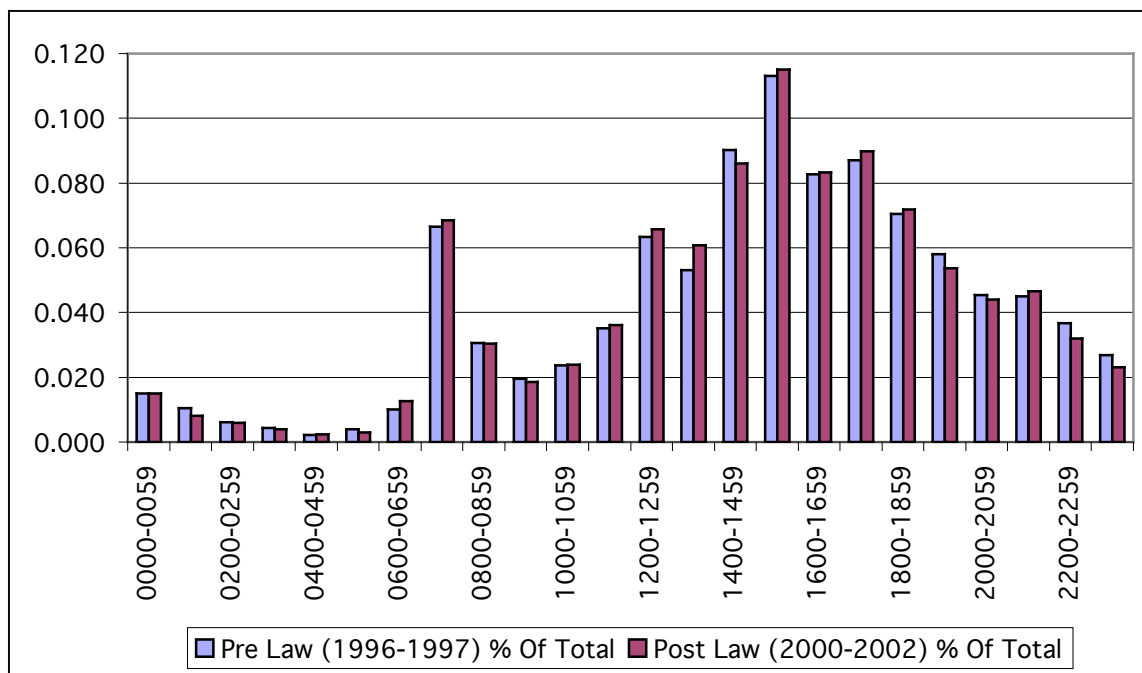
Table 3.2: Estimated Passenger Deaths and Injuries Prevented

Year	Passengers "Saved"	Degree Of Injury				
		None	Killed	Severe	Visible	Pain
1999	387	201	2	9	69	106
2000	897	466	5	21	159	246
2001	936	486	5	21	166	257
2002	1301	676	7	30	231	357

4.0 Crashes By Time Of Day

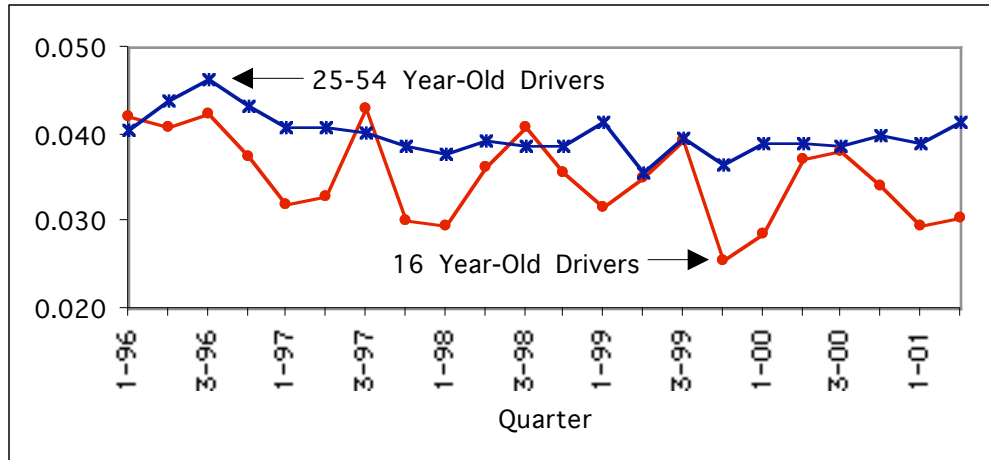
There is convincing evidence in the literature that the accident involvement rates of young drivers vary by time of day. While nighttime driving is riskier than daytime for everyone, it is especially so for teens (Doherty et al., 1998; Williams and Wells 1995; Massie et al., 1995). For this reason, one of the key provisions of the graduated licensing law is the imposition of a curfew between the hours of midnight and 5:00 AM for the first year that a provisional license is held. Figure 18 shows the distribution of fatal and injury crashes by 16 year-old involved drivers for the two years prior to the new law (January 1996 to December 1997) and the last two years for which we have crash data (January 2000 to December 2002).

Figure 4.1: Distribution Of 16 Year-Old Involved Crashes By Time Of Day



If the curfew has had an effect on the driving habits of 16 year-olds, we would expect to see a change in the percentage of their crashes occurring during that time. Figure 18 does show a decrease in the percentage of 16 involved crashes during all five hours of curfew. To test the significance of the changes, regression analysis was performed on the quarterly percentage of curfew crashes for both 16 and 25-54 year-olds. Quarterly data was used due to the relatively small number of curfew crashes for 16 year-olds. Graphical representation of the curfew percentages for both groups is shown in Figure 19.

Figure 4.2: Percentage of Crashes Occurring During Curfew



For both age groups there is a long term downtrend which is highly significant for 25-54 year-olds ($p = 0.01$) and nearly significant for 16 year-olds ($p = 0.12$). For the older group there is also a highly significant reversal in direction just after the change in the licensing law, with the percentage of crashes occurring during curfew starting to rise at that point. For 16 year-olds there was a small, non-significant lessening of the long-term downward trend at the time of the implementation of the new law. The new law does not appear to have had a material effect on the percentage of driving done by 16 year-olds during curfew hours. This percentage was in a downtrend prior to the law and continued after the law took effect.

5.0 Discussion

In the four and on half years following implementation of the new law, the increased practice requirements and restrictions on passengers have caused the crash rate for 16 year-old drivers to decline by 11% (3.09 to 2.77) and the average number of teen-age passengers carried by 16 year-olds to decrease by approximately 31% (from 0.77 to 0.53). The combination of these two decreases resulted in an estimated saving of 29 lives and the prevention of 2,632 injuries.

Restrictions on driving between midnight and 5 AM do not appear to have had a material effect on the percentage of driving done by 16 year-olds during those hours. This percentage was in a downtrend prior to the law and continued after the law took effect.

The new law appears to have made obtaining a driver's license slightly less attractive as evidenced by an increase in the median licensing age for 16 & 17 from 16 years six months to 16 years eight months.

One important factor working against the efficacy of the new law is that it is very difficult to enforce since there is no way to tell if a specific car has a driver who is violating the law. It is only after a car has been stopped for some other violation that the conditions of the graduated licensing law can be checked. Additionally, there appears to be a great deal of reluctance on the part of law enforcement personnel to cite drivers even when they are found in violation. As an example, during the years 1999 and 2000, in the entire state, the CHP wrote only 252 and 832 citations, respectively, for violations of the graduated licensing law.

6.0 Conclusions and Recommendations

The July 1998 changes to California's graduated driver licensing laws (GDL) for new drivers under the age of 18 has had a significant effect on 16 year-old drivers. While there was a great deal of initial resistance and resentment among teens, the law has been effect long enough to be accepted. It is important for legislators and the general public be made aware of the law's success and that we continue to work to increase its benefits.

The key to the law's success appears to be the restriction on teen passengers. Since carrying teen passengers has been shown to increase the risk of teen crashes, this part of the GDL law has had the dual effect of reducing crashes as well as reducing the number of people involved when a crash occurs. The effect of increasing the period of passenger restrictions (currently it only covers the first six months) should be explored further.

Another area that should be looked into is the curfew. The current included hours, midnight to 5:00 AM, saw little teenage traffic before the GDL law and very little change after. Other states have experimented with earlier curfews with some success. Currently 10% of crashes involving 16 year-old drivers in California occur between 9:00 PM and midnight. Beginning the curfew at an earlier time could have a material effect on teen crashes. A detailed study of states with different curfews than California's would go a long way toward validating this possibility.

Where the variable $y_t = C_t, D_t, \text{ or } C_t / D_t$. Thus, in the BP terminology, this is a pure structural change model, where $p=0$, and $z_t = 1 \forall t$.²

We follow the procedure suggested in Bai and Perron (2002). First, we calculate the UDMAX and WDMAX statistics. These are double maximum tests, where the null hypothesis of no structural breaks is tested against the alternative of an unknown number of breaks. These tests are used to determine if at least one structural break is present. In addition, the SupF(0| l) is a series of Wald tests for the hypothesis of 0 breaks vs. l breaks. If these tests show evidence of at least one structural break, then the number of breaks can be determined by the Bayesian Information Criteria (BIC), a SupF($l+1|l$) test and sequential application of the SupF($l+1|l$) test. These three tests will not necessarily give the same answer for the number of breaks or the break dates. In the results presented below, these tests are consistent in estimating the number of breaks, but there is some minor variation in estimating the break dates. In these latter cases we follow BP(2002), who recommend relying on the sequential test results.

¹ Details can be found in Bai and Perron (2002).

² The model of pure structural change as a break in the mean of a series has been applied in several papers. Hamilton (1988) uses a two state Markov model and finds a change in the regime of the mean of the U.S. nominal interest rate between late 1979 and late 1982; Garcia and Perron (1996) use a similar methodology to analyze the question of whether there are breaks in the mean of the U.S. real interest rate series for the U.S. over the period 1961 to 1986. Caporale and Grier (2000) use the BP methodology to uncover breaks in the mean of the U.S. real interest rate and shifts in political regime; Atkins (2002) uses the BP methodology to uncover breaks in the mean of the Canadian and U.S. nominal interest rates and inflation rates; Bai and Perron (2002) apply the BP methodology to the U.S. real interest rate and the U.K. Phillips curve..

Testing for the Existence of Breaks

The results (not presented) from applying the UDMAX, WDMAX, and SupF(0//) tests, for each of the three variables, were consistent with at least one break in each series. Therefore, we proceed to test for the number of breaks, and to identify the break dates. These results are presented on Table A1

Table A1
Estimated Breaks

	C_t	D_t	C_t / D_t
SupF(2 1)	12.72	121.38	8.91
SupF(3 2)	11.70	75.54	6.90
SupF(4 3)	13.38	76.05	-
SupF(5 4)	5.74	28.11	-
BIC	3	5	1
Sequential Procedure	4	5	1
$\hat{\delta}_1$	309.50	98,977	
s.e.	(6.06)	(685.77)	
$\hat{\delta}_2$	360.75	103,489	3.09
s.e.	(12.48)	(767.85)	(0.047)
$\hat{\delta}_3$	283.14	117,016	2.76
s.e.	(4.61)	(2,365.91)	(0.032)
$\hat{\delta}_4$	264.53	92,495	-
s.e.	(2.91)	(653.40)	-
$\hat{\delta}_5$	299.05	101,388	
s.e.	(8.27)	(484.49)	
$\hat{\delta}_6$	-	108,638	
	-	(627.39)	
\hat{T}_1	98:04	97:10	98:11
95% c.i.	97:09-98:08	97:06-98:03	98:06-99:06
\hat{T}_2	98:12	98:05	-
95% c.i.	98:10-99:03	98:01-99:06	-
\hat{T}_3	99:07	99:02	-
95% c.i.	98:08-99:12	98:12-99:03	-
\hat{T}_4	02:05	01:02	
95% c.i.	01:11-02:08	00:12-01:03	
\hat{T}_5	-	02:02	
95% c.i.	-	01:12-02:03	

On Table 2, results are consistent with 4 breaks in the number of at fault accidents, 5 breaks in the number of drivers and 1 break in the at fault accident rate.

The raw data on each of the variables, along with the mean estimated for each of the regimes implied by the results on Table 1 are shown on Figures 1-3.

Figure A1: Number of 16 Year Old At Fault Accidents
July 1996 – December 2002

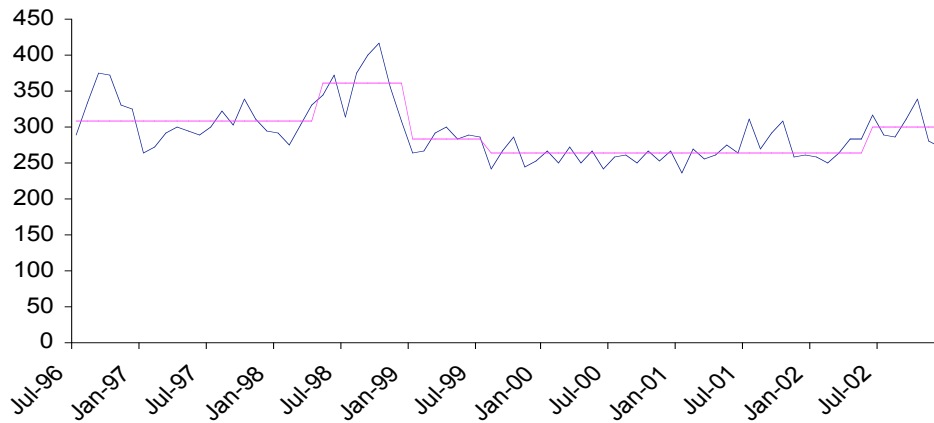


Figure A2: Number of 16 Year Old Drivers
July 1996 – December 2002

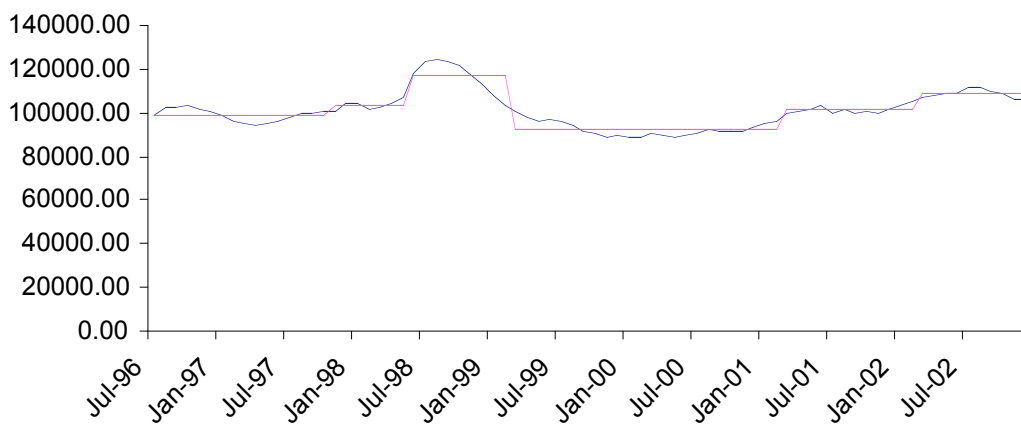
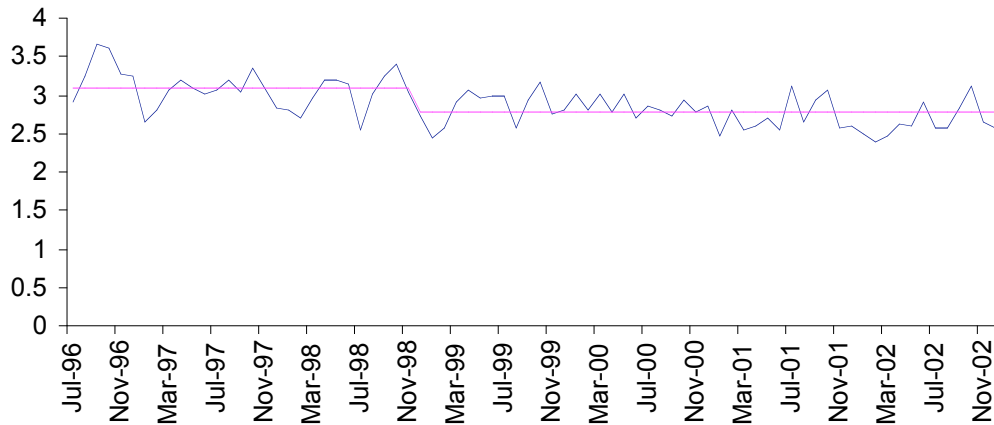


Figure A3: 16 Year Old At Fault Accident Rate
July 1996 – December 2002

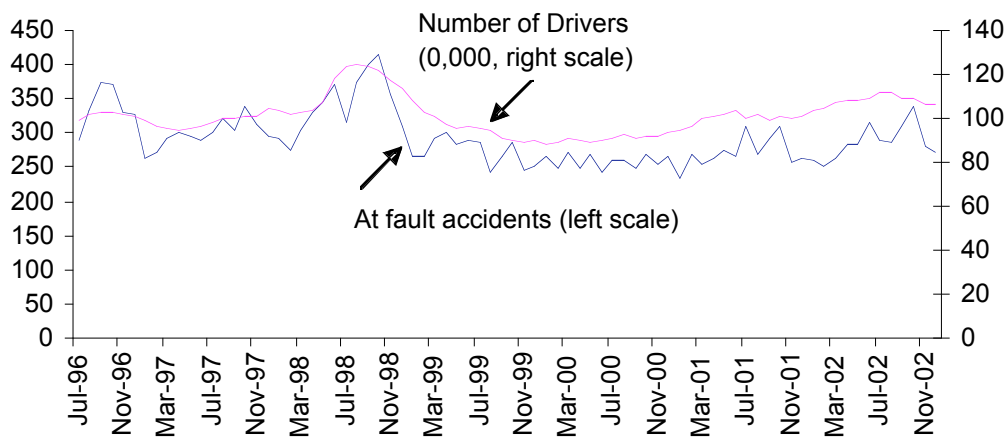


The overriding feature of the above results is that there is a permanent break in the age 16 at fault accident rate in November, 1998, when the rate fell from 3.09 to 2.76.

Discussion of the results

In discussing these results, it may be helpful to refer to Figure 4, which plots the number of drivers with the number of accidents.

Figure A4: Number of Drivers and At-Fault Accidents



The number of drivers begins to increase at some point in mid 1997. The BP technique picks up the first break in October, 1997, when the mean number of drivers increases from 98,977 to 103,489. This increase continues through 1998, with another mean increase detected in May, 1998. Notice that this increase peaks at some point in late 1998, early, 1999. It appears that approximately 5,000 16 year olds shifted their decisions to become drivers early, in anticipation of the change in

legislation. The technique picks the peak at February, 1999. At the same time that the number of drivers is increasing, the number of at fault accidents is also increasing throughout 1998. Between July, 1996 and April, 1998, the mean number of at fault accidents is 309.5, and this increases to 360.75 over the period May, 1998 to December, 1998. The important point to note here is that, throughout the period of the increase in the number of drivers, there is a proportionate increase in the number of accidents, and, therefore, during this period, the mean at fault accident rate remains statistically constant at 3.09. Thus, for this period, the number of accidents is following the number of drivers in an equilibrium regime. This is the equilibrium regime that is in force prior to the enactment of the legislation.

Beginning in late 1998 or early 1999, the number of drivers begins to decrease. Between March 1999 and February, 2001 the mean number of drivers decrease to 97,495. At the same time, the number of at fault accidents begins to decrease. Between January, 1999 and July, 1999, the mean number of at fault accidents decreases to 283.14, and between August, 1999 and May, 2002, there is a further decrease to 264.28. However, the number of at fault accidents is falling proportionally more than the number of drivers, as the mean at fault accident rate fall to 2.76. Thus, once again, the number of accidents is responding to the number of drivers, but now there is a regime shift, so that the number of accidents per driver has decreased.

Notice that there is a confirmation of this new regime towards the end of the sample. In February, 2002, the mean number of drivers increases to 108,638. This would be consistent with the last phase of driver adjustment in response to the legislation. First, the number of drivers increased in anticipation of the legislation. Then there were less drivers, as an unusual bulge went through the system. Finally, the number of drivers increases to reflect the last stage of adjustment. During this final stage of adjustment in the number of drivers, the number of at fault accidents increases. However, this increase obeys the new relationship between drivers and accidents, as the accident rate remains constant at 2.76.

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