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Public policies and motorcycle safety

Michael T. French[a,*], Gulcin Gumus[b,c], Jenny F. Homer[d]

[a] Health Economics Research Group, Department of Sociology, Department of Epidemiology and Public Health, and Department of Economics, University of Miami, 5202 University Drive, Merrick Building, Room 121F, P.O. Box 248162, Coral Gables, FL 33124-2030, USA

[b] Department of Health Policy and Management, Department of Economics, Florida International University, 11200 S.W. 8th Street, HLSII 554A, Miami, FL 33199, USA

[c] IZA, Bonn, Germany

[d] Health Economics Research Group, Department of Sociology, University of Miami, Sociology Research Center, 5665 Ponce de Leon Blvd., Flipse Building, Room 104, P.O. Box 248251, Coral Gables, FL 33124-0719, USA

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ABSTRACT

Numerous studies have examined the effectiveness of alcohol and traffic policies in reducing automobile crashes and fatalities, but only a few have analyzed the impact of state-specific policies on motorcycle safety. Given the growing popularity and inherent safety risks of motorcycle riding, this study provides a comprehensive investigation of both fatal and non-fatal injuries. State-level longitudinal data from 1990 to 2005 are analyzed to determine how various alcohol and traffic policies impact motorcycle safety and whether there are differential effects by type of injury. The results consistently show that universal helmet laws have the most significant effect on both non-fatal and fatal injuries. Mandatory rider education programs and speed limits on rural interstates significantly impact non-fatal injuries.

"There are two types of motorcyclists: those who have fallen and those who will." Motorcycle Safety Foundation (MSF) Instructor

1. Introduction

Although motorcycle riding has become increasingly popular in recent years, it remains a risky form of transportation. Motorcycle registrations in the U.S. increased from 4.26 million in 1990 to 6.69 million in 2006 (National Highway Traffic Safety Administration [NHTSA], 2007), while motorcycle sales increased from 278,000 units in 1992 to 1.1 million units in 2007 (Motorcycle Industry Council, 2006; Welsh, 2008). The number of motorcycle rider fatalities declined throughout the 1980s and early 1990s but began increasing in the late 1990s. According to the NHTSA (2008), 4810 motorcycle riders were killed and 88,000 were injured in the U.S. in 2006.[1] During this same time period, the number of registered passenger cars increased from 123 million in 1990 to 136 million in 2006 while the number of passenger car occupants killed decreased from 24,092 to 17,800 (NHTSA, 2007).

A large proportion of motorcycle crashes and fatalities involve riders who lack a proper license or training, are speeding, and/or are not wearing a safety helmet (Hurt et al., 1981; NHTSA, 2008). Increases in motorcyclist fatalities may also be related to the decisions of several states to rescind helmet laws after Congress eliminated sanctions against states without universal helmet laws in 1995 (Sass and Zimmerman, 2000; Houston and Richardson, 2008). An obvious risk factor for motorcyclists that has received little attention in the literature is alcohol consumption. An estimated 34 percent of all motorcyclists who were fatally injured in 2006 had BAC levels above 0.01 g/dL (NHTSA, 2008). Riding a motorcycle requires more strength, coordination, and attention than driving an automobile, all of which can be severely impaired after consuming several alcoholic drinks.

In light of the increases in fatal and non-fatal motorcycle rider injuries and the public health burden associated with motorcycle crashes, a Department of Transportation Report (U.S. Department of Transportation, 2007) recently referred to motorcycle fatalities as "our Nation's greatest highway safety challenge." The present study contributes important new information in this area by

* Corresponding author. Tel.: +1 305 284 6039; fax: +1 305 284 5310.
E-mail addresses: mfrench@miami.edu (M.T. French), gumusg@fiu.edu (G. Gumus), jhomer@miami.edu (J.F. Homer).

[1] Figures displaying these trends can be found in French et al. (2008).

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focusing on three alcohol policies and three traffic policies to determine whether policy interventions can be effective in improving motorcycle safety. Unlike most existing studies of automobile and motorcycle safety, we examine predictors of non-fatal as well as fatal motorcycle injuries using an extensive set of state-specific longitudinal data from 1990 to 2005. The study findings provide initial guidance for the formulation of policy and rider safety recommendations and are used to highlight areas for future research.

2. Background

The role of public policies in reducing fatalities among passenger car occupants has been studied extensively. Rigorous econometric methods have been applied to more accurately assess the impact of these policies by taking into account differences across states and time, simultaneous changes in other policies, and environmental conditions that could influence drinking behavior (Ruhm, 1996; Mast et al., 1999; Eisenberg, 2003; Morrisey and Grabowski, 2005). Research indicates that more stringent BAC laws (Dee, 2001; Shults et al., 2001; Eisenberg, 2003), zero tolerance laws (Shults et al., 2001; Carpenter, 2004), administrative license revocation (ALR) (Grabowski and Morrisey, 2001; Freeman, 2007), and speed limits (Grabowski and Morrisey, 2007) can all reduce motor vehicle fatalities. Two recent studies reported small or non-significant effects of BAC laws on motor vehicle fatalities (Eisenberg, 2003; Freeman, 2007). Several studies have found higher beer taxes to be associated with fewer motor vehicle fatalities (e.g., Chaloupka et al., 1993; Ruhm, 1996), but more recent research has questioned the magnitude of these estimates (e.g., Dee, 1999; Mast et al., 1999; Grabowski and Morrisey, 2001; Young and Bielinska-Kwapisz, 2006).

This literature suffers from two major limitations. First, relatively few studies have examined the effects of alcohol and other traffic policies on traffic safety for specific types of vehicles such as motorcycles. Motorcycles account for a greater proportion of fatalities (11 percent in 2006) than their share of registered vehicles (3 percent), indicating that this is an important area to research (NHTSA, 2008). Second, the vast majority of motor vehicle studies analyze fatality data from the Fatality Analysis Reporting System (FARS), a surveillance system administered by the NHTSA.[2] Although non-fatal injuries far outnumber fatalities, the federal government has not assembled a comparable and publicly available reporting system for non-fatal injuries in all 50 states.[3]

Carpenter and Stehr (2008) used the FARS to evaluate whether seatbelt policies reduced serious non-fatal injuries. Because the FARS collects data on crashes where at least one fatality occurred, the analysis could only assess whether seatbelt policies affect non-fatal injuries that occur in crashes with at least one fatality. In an example from the motorcycle literature, Coben et al. (2007) used data from the Healthcare Cost and Utilization Project, which included cross-sectional hospital discharge records from 33 states in 2001. The authors showed that motorcycle-related hospitalizations in states without universal helmet laws were more likely to involve a death during hospitalization or a more serious injury than hospitalizations in states with universal helmet laws.

As a result of data limitations, much of the existing research on motorcycle safety is either descriptive, published as government reports, or primarily based on narrow samples from hospital discharge data, traffic crash records, or police records from a particular state or a small number of states over a short period of time. Nevertheless, these studies have provided valuable information about motorcyclists and their patterns of risky behaviors (Hurt et al., 1981; Max et al., 1998). Research shows that motorcyclists under the influence of alcohol are less likely to use helmets (Peek-Asa and Kraus, 1996; Bledsoe and Li, 2005) and more likely to speed, drive without a valid license, and be involved in single-vehicle crashes (Peek-Asa and Kraus, 1996; Shankar, 2003). Two studies suggest that motorcycle operators become impaired (i.e., unable to safely drive their vehicles) at lower BAC levels than other motor vehicle operators (Colburn et al., 1993; Sun et al., 1998).

With the exception of universal helmet laws, which are strongly associated with lower motorcycle fatality rates in numerous studies (Sass and Zimmerman, 2000; Bledsoe and Li, 2005; Houston and Richardson, 2008; Dee, 2009), only a few studies have examined whether other state policies can be used to reduce risky behaviors among motorcyclists. Villaveces et al. (2003) compared motorcycle fatality rates when certain alcohol-related policies were in effect between 1980 and 1997 to rates when these policies did not exist. ALR laws were associated with reductions in all types of motorcycle fatalities while stricter BAC laws were strongly associated with lower motorcycle fatality rates for crashes involving alcohol. Each policy was considered separately without taking into account other policies or factors that might affect fatality rates. Houston and Richardson (2008) evaluated the effects of motorcycle helmet policies on fatalities while controlling for the minimum legal drinking age, 0.08 BAC per se limit, and speed limit. Of these three policy controls, only minimum legal drinking age was significantly associated with lower fatality rates, and only in certain models. Although some research has supported the effectiveness of rider education programs in reducing motorcycle crashes and fatalities, estimates of the effect of mandatory programs are not available (Billheimer, 1998; McGwin et al., 2004). Rider education programs are important components of motorcycle safety initiatives supported by rider groups as well as the NHTSA (NHTSA, 2008).

Sass and Zimmerman (2000) conducted one of the few studies that used a methodology similar to ours to investigate the association between universal helmet laws and motorcycle fatalities. They analyzed panel data from 1976 to 1997 and controlled for demographic variables, seat belt policies, speed limits, and alcohol consumption. Accounting for state and year fixed-effects, they found that helmet laws, alcohol consumption, and per capita police employment (as a measure of enforcement) were significantly associated with annual adjusted motorcycle fatalities. Yet this analysis only included data up to 1997, the year when motorcycle fatalities began increasing again in the United States. Using more recent data could reveal additional factors that have contributed to the upward trend in fatalities. In addition, instead of evaluating specific alcohol policies such as BAC limits and DUI laws, Sass and Zimmerman (2000) used alcohol consumption per capita as a composite measure of the impact of these alcohol policies. Consequently, the role of specific alcohol policies could not be determined.

Based on this comprehensive review of existing studies, we believe that the current analysis contributes to the motorcycle safety literature in several important ways. First, it features a unique longitudinal dataset on both fatal and non-fatal motorcycle injuries compiled from numerous government reports and personal correspondence with representatives from many state agencies. Second, unlike most of the motorcycle studies noted above, it evaluates

[2] FARS contains detailed data from law enforcement reports about motor vehicle crashes that occurred on public roads in the United States and resulted in a fatality up to 30 days after the crash.

[3] Since 1988, the National Automotive Sampling System General Estimates System has collected data on motor vehicle crashes (from a nationally representative sample of police reports) that lead to a fatality, injury (possible, non-incapacitating, incapacitating), or major property damage, but state identifiers are currently not being made available. The National Electronic Injury Surveillance System, a program to monitor injuries related to consumer products from a nationally representative sample of 99 hospitals in the United States, only began including information on car and motorcycle-related injuries in 2000 (Christoffel and Gallagher, 2006).

Table 1
Variable definitions and summary statistics (*N* = 768 unless indicated otherwise).

Variable	Definition	Mean	St.Dev.	Min	Max
Total non-fatal injuries (*N* = 574)[a]	Total non-fatal motorcycle rider injuries	1472	1590	69	11,043
Non-fatal injuries per 100,000 people (*N* = 574)[a]	Non-fatal motorcycle rider injuries per 100,000 population of age 15 and above	37.392	15.594	8.266	138.197
Total fatal injuries	Total fatal motorcycle rider injuries	56.997	65.603	1	563
Fatal injuries per 100,000 people	Fatal motorcycle rider injuries per 100,000 population of age 15 and above	1.401	0.639	0.195	4.798
Motorcycle registrations per 100,000 people[b]	Number of two-wheeled and three-wheeled motorcycles per 100,000 population of age 15 and above	2475	1347	614	8,850
Traffic policies					
Universal helmet law	Mandatory helmet requirement for all riders	0.469	0.499	0	1
Mandatory rider education program	State legislated or sponsored rider education program that is mandatory for all or some riders	0.419	0.494	0	1
Speed limit on rural interstates[c]	Maximum legal speed limit on rural interstates (mph)	66.914	4.809	55	75
Alcohol policies					
BAC limit ≤ 0.08[d]	Maximum allowable blood alcohol concentration (BAC) of driver ≤0.08 g/dL	0.374	0.484	0	1
Zero tolerance laws	Zero tolerance law with the BAC limit = 0.00 g/dL for individuals under age 21	0.177	0.382	0	1
Administrative license revocation	Law enforcement can suspend or revoke a license of someone who fails/refuses to take an alcohol test after a traffic stop or vehicle crash	0.738	0.440	0	1

[a] Data on motorcycle non-fatal injuries for the states of New Jersey, Vermont, and Washington were not available for any year of our analysis period. In addition, state- and year-specific non-fatal injury data were missing for an additional 146 observations.
[b] Includes mopeds and scooters in states that require them to be registered.
[c] Three state/year observations did not have an explicit speed limit; and were assigned the highest observed speed limit of 75 mph.
[d] Six state/year observations did not have an explicit BAC limit and were assigned the highest observed BAC limit of 0.12.

multiple public policies and employs statistical methods capable of accounting for many of the relevant factors and policies. To our knowledge, the present study is the first to apply rigorous econometric methods to a large dataset on fatal and non-fatal motorcycle injuries, alcohol and traffic policies, and many other state-specific control variables. These estimation techniques have been applied to automobile-specific data but have not been extended to motorcycle riders. Thus, the results provide new insight into the relationships between alcohol policies, traffic policies, and fatal and non-fatal motorcycle injuries.

3. Data

This study uses state-specific longitudinal data for the continental U.S. from 1990 to 2005 to evaluate the effects of alcohol and traffic safety policies on motorcycle rider fatal and non-fatal injuries.[4] The list of variable definitions for the injury measures and policy variables can be found in Table 1. French et al. (2008) present the full list of sources for all variables. Consistent with the previous literature, we exclude Alaska, Hawaii, and the District of Columbia.

3.1. Outcome measures

Previous studies of traffic fatalities have estimated the effect of policies on the fatality rate (i.e., number of fatalities per capita or per vehicle mile traveled) (e.g. Ruhm, 1996; Dee, 1999, 2001; Sass and Zimmerman, 2000; Eisenberg, 2003; Freeman, 2007; Houston and Richardson, 2008). Since state- and year-specific data on the number of licensed motorcycle riders and motorcycle vehicle miles traveled are not available, we evaluated the effects of public policies on three main fatal and non-fatal injury measures: total motorcycle rider fatality count, fatalities per 100,000 people aged 15 years and older, and non-fatal injuries per 100,000 people aged 15 years and older.

Fatality figures were requested from the FARS, the surveillance system administered by the NHTSA.[5] As part of our robustness checks, we used the extensive crash characteristics available in FARS to investigate whether public policies have differential impacts on six additional outcomes (weekend, weekday, nighttime, daytime, single-vehicle, and multi-vehicle fatalities). Weekend fatalities were defined as motorcycle riders killed in traffic crashes occurring between 6:00 p.m. on Friday and 6:00 a.m. on Monday. Weekday fatalities occur between 6:00 a.m. on Monday and 6:00 p.m. on Friday. Daytime fatalities occur between 6:00 a.m. and 6:00 p.m., and nighttime fatalities occur between 6:00 p.m. and 6:00 a.m. Motorcyclist fatalities that occurred in crashes involving only motorcycles are referred to as "single-vehicle fatalities" while those that occurred in crashes involving other types of vehicles are referred to as "multi-vehicle fatalities." All fatality data used in this study were based only on motorcycles and exclude scooters, mopeds, and off-road vehicles.

Given the lack of a national registry or other database comparable to FARS for non-fatal injuries, we contacted individual state agencies to request total annual counts of non-fatal motorcycle

[4] "Motorcyclist" in this paper is a term that refers both to motorcycle drivers and to passengers.

[5] Data requests can be made through the FARS website (www.fars.nhtsa.dog.gov).

injuries beginning in 1990. Although some states included mopeds and scooters in their injury counts and were not able to separate them out, these vehicles make up a very small proportion of all two-wheeled vehicles in any state. Since a few states did not collect any injury data and not all states had complete data for every year, thus the panel used in this analysis is unbalanced.[6] Despite the different reporting systems for fatal and non-fatal motorcycle injuries, investigative analyses confirm that the within-state trends are similar (French et al., 2008).[7]

3.2. Policy variables

3.2.1. Alcohol policies

Three binary indicators were constructed to identify whether a state had an ALR policy, a zero tolerance law (a law mandating a BAC limit of 0.00 for drivers under 21 years of age), and a BAC limit of less than or equal to 0.08 g/dL. In states with an ALR policy, licensing authorities or law enforcement can suspend or revoke an individual's license if a driver fails or refuses to take an alcohol test after a traffic stop or vehicle crash. Given concerns about the minimal within-state variations over time in alcohol taxes (Dee, 1999; Young and Bielinska-Kwapisz, 2006), we did not include this policy in our core specifications and instead used it to test the sensitivity of our estimates.

We expect that the presence of more stringent alcohol policies will reduce motorcycle fatalities in several ways. First, motorcyclists may abstain from drinking before riding or may ride more carefully if they have been drinking. Second, they might actually change their riding patterns by riding less frequently or using a different means of transportation when they plan on drinking. Finally, these policies could influence the drinking and driving behavior of other drivers, making the roads safer for motorcyclists and possibly decreasing the risk of a collision with another motor vehicle.

3.2.2. Traffic policies

The maximum speed limit in each state was entered as a continuous variable, while the presence of a universal helmet law (requiring riders of all ages to use a helmet) and a mandatory rider education program (for all or some riders) were included as dichotomous measures.

Studies have reported that motor vehicle fatality rates increased in states that raised their speed limits (Grabowski and Morrisey, 2007). Traveling at higher speeds makes avoiding a crash more difficult and, if a crash occurs, may lead to more severe consequences. Although the alcohol policies and maximum speed limit apply to motorcycle riders as well as drivers of other types of motor vehicles, universal helmet policies and mandatory rider education programs are intended to affect motorcycle safety by directly impacting the behavior of motorcycle operators. Helmet use and universal helmet laws have consistently been associated with lower fatalities (Sass and Zimmerman, 2000; Bledsoe and Li, 2005; Houston and Richardson, 2008), injury severity (Rowland et al., 1996), and medical costs (Max et al., 1998; Bledsoe et al., 2002). As of 2006, 47 states had legislated motorcycle rider education programs, which are intended to prevent or reduce the likelihood of crashes. These courses are required for certain riders (e.g., young riders) prior to licensing in some states. Universal helmet laws and mandatory rider education programs are expected to be associated with fewer motorcycle fatalities and injuries.

3.3. Control variables

A number of control variables are included in the analysis to account for demographic, economic, geographic, and traffic conditions as well as motorcycle usage. The number of motorcycle registrations is included as an exposure variable in all models since motorcycle fatalities and injuries occur more frequently in states with more motorcycles.[8] Other control variables include the unemployment rate, income per capita, average annual temperature and precipitation, gasoline prices, lane miles per mile of total public roads, highway maintenance funds per mile of total public roads, and motor vehicle fatalities per 10,000 registered vehicles. We generated two traffic density variables, one for urban and another for rural areas, by dividing the annual millions of vehicle miles traveled per 1000 residents. Demographic controls included percentage of young drivers, percentage of white residents, percentage of residents with a bachelor's or higher degree, and average household size.

4. Methods

Fatal and non-fatal motorcycle injuries exhibit both between-state and within-state variation over time. Several previous studies examining how public policies affect motor vehicle fatalities have addressed unobserved heterogeneity by using panel data techniques and modeling these state-specific factors as time-invariant fixed-effects (Ruhm, 1996; Dee, 1999; Morrisey and Grabowski, 2005; Freeman, 2007).

Using an approach similar to the earlier literature on motor vehicle fatalities, we define motorcycle injuries by state and year as a function of the following form:

$$y_{st} = f(A_{st}, M_{st}, C_{st}) \tag{1}$$

where y_{st} indicates either fatal or non-fatal injuries for state s in year t, A_{st} is a vector of alcohol policy measures, M_{st} is a vector of automobile and motorcycle traffic safety policies, and C_{st} is a vector of other controls such as economic, demographic, and environmental factors. Time period t refers to calendar years from 1990 to 2005, and state s refers to each state. Fatal and non-fatal injuries depend on the observable factors listed above as well as on unobserved state-specific fixed-effects.

The injury rates depend on the intensity of motorcycle use in each state and year, for which we proxy by using the number of motorcycle registrations per 100,000 people.[9] Hence, we first estimate the following fixed-effects linear regression:

$$y_{st} = \mu_s + \delta_t + A_{st}\beta_1 + M_{st}\beta_2 + C_{st}\beta_3 + \varepsilon_{st} \tag{2}$$

[6] Data on non-fatal motorcycle-related injuries for the states of New Jersey, Vermont, and Washington were not available for any year of our analysis period. In addition, state- and year-specific non-fatal injury data were missing for an additional 146 observations (mostly for earlier years).

[7] To the extent possible, we further examined the reliability of the non-fatal injury data. At the national level, the trends in non-fatal and fatal injury measures are quite consistent (French et al., 2008). For the entire sample, there is a strong correlation (0.673, $N = 574$, $p < 0.001$) between fatalities per 10,000 people and injuries per 10,000 people. A close examination of the variation in each of these measures as compared to the averages, as well as the comparison of the within-state variation to the overall variation, reveals that fatal and non-fatal injury counts display similar patterns. They also display similar trends within each state (French et al., 2008). Although we are unable to confirm the reliability of the reporting system in each state, we are reasonably confident that the states collected and reported non-fatal injury data consistently vis-à-vis the national fatality data.

[8] Mopeds and scooters are included in registration data in states that require these vehicles to be registered.

[9] Another option we considered for the exposure variable was the number of new motorcycle units sold each year in each state. Since current sales represent only a small portion of the total motorcycles in use in a particular year, we decided to use motorcycle registrations instead.

Table 2
Estimation results for non-fatal and fatal motorcycle injuries.

	Non-fatal injuries per 100,000 people (fixed-effects OLS)		Fatal injuries per 100,000 people (fixed-effects OLS)		Fatal injury count (conditional fixed-effects negative binomial)	
	(1)	(2)	(3)	(4)	(5)	(6)
Universal helmet law	−6.605*** (1.452)	−7.386*** (1.472)	−0.444*** (0.076)	−0.415*** (0.077)	−0.254*** (0.028) [0.776]	−0.240*** (0.031) [0.786]
Mandatory rider education	−3.333** (1.471)	−3.806** (1.488)	−0.059 (0.087)	−0.105 (0.089)	0.030 (0.044) [1.030]	0.010 (0.046) [1.010]
Speed limit on rural interstates/10	−5.034*** (1.142)	−4.137*** (1.186)	0.015 (0.056)	−0.068 (0.063)	0.102*** (0.029) [1.108]	0.034 (0.033) [1.035]
BAC limit ≤ 0.08	−1.031 (0.811)	0.117 (0.817)	0.049 (0.046)	0.010 (0.048)	0.007 (0.021) [1.007]	0.005 (0.022) [1.005]
Zero tolerance law	−0.159 (1.120)	0.672 (1.119)	0.052 (0.062)	0.006 (0.063)	0.032 (0.028) [1.032]	0.011 (0.028) [1.011]
Administrative license revocation	3.427** (1.407)	3.689*** (1.388)	0.062 (0.067)	0.070 (0.067)	0.007 (0.033) [1.007]	0.009 (0.032) [1.009]
State and year fixed-effects	Yes	Yes	Yes	Yes	Yes	Yes
State-specific controls	No	Yes	No	Yes	No	Yes
Number of observations	574	574	768	768	768	768
Log-likelihood	−1744.52	−1713.19	−261.52	−240.56	−2385.47	−2355.07

Notes: state-specific controls include the unemployment rate, income per capita, average annual temperature, average annual precipitation, gasoline prices, annual urban and rural millions of vehicle miles traveled per 1000 residents, lane miles per mile of total public roads, highway maintenance funds per mile of total public roads, motor vehicle fatalities per 10,000 registered vehicles, percentage of young drivers, percentage of white residents, residents with bachelor's or higher degree, and the average household size. Each specification also includes motorcycle registrations as described in the text. For each explanatory variable in columns 1–4, we report the estimated coefficient and the estimated standard errors in parentheses. In columns 5 and 6, we also report the incidence rate ratios [IRR] in brackets and statistical significance is based on the test of the null hypothesis that IRR = 1.

** Significance at the 5% level.

*** Significance at the 1% level.

where the fatal or non-fatal injury rates are regressed directly on alcohol and traffic policies and a set of controls, μ_s and δ_t denote the unobserved state-specific and year-specific determinants of motorcycle injuries, and ε_{st} is the error term, which is assumed to follow a normal distribution.

Since our data reveal a small number of motorcycle fatalities in many states and years, employing count models may be more appropriate than using fatality rates in this case (Grant and Rutner, 2004; Morrisey and Grabowski, 2005). Given the nature of the underlying data, we also estimate a model for fatal injury counts using a conditional fixed-effects count data technique proposed by Hausman et al. (1984). In a conditional fixed-effects Poisson framework, the count of fatalities (y_{st}) is assumed to have a Poisson distribution with parameter λ_{st}, and the unobserved heterogeneity is modeled as state-specific fixed-effects denoted by μ_s. The Poisson parameter λ is a deterministic function of the observed factors listed above as well as the state-specific and year-specific fixed-effects according to the following expression:

$$\lambda_{st} = \exp(\mu_s + \delta_t + A_{st}\beta_1 + M_{st}\beta_2 + C_{st}\beta_3) \quad (3)$$

Because the fatality counts across states exhibit considerable variation leading to a high degree of overdispersion, the negative binomial technique was chosen for the core analysis, but Poisson regressions were included in the sensitivity analyses. The negative binomial technique is a more flexible alternative to Poisson regression in the presence of overdispersion. Both models are estimated by maximum likelihood and the estimation is conditional on the total count of fatalities in each state. In our count data models, the logarithm of motorcycle registrations was used as a proxy for the intensity of motorcycle use in each state and year (i.e., exposure).

In both linear regression and count models, the coefficients of interest are contained in the vectors β_1 and β_2.[10] The direction, magnitude, and significance of the coefficients attached to the alcohol and traffic policies indicate whether these policy tools have a meaningful effect on motorcycle safety.

5. Results

Table 1 contains descriptive statistics (mean, standard deviation, and range) for the outcome and policy variables used in the analysis. The average count of non-fatal injuries is 1472 whereas the average count of fatalities across all states and years is approximately 57. As indicated by the range and standard deviations, wide variation exists in both of these measures, even when adjusted for the size of the population. Non-fatal injuries per 100,000 people varies between 8.3 and 138.2 across all years and states, and fatal injuries per 100,000 people ranges between 0.2 and 4.8.

In terms of traffic policies, less than half of the state/year observations had a universal helmet law or mandatory rider education program. The speed limit on rural interstates ranged from 55 mph to 75 mph during the analysis period. Although many states had zero tolerance laws during this period, those with a strict youth BAC limit of 0.00 make up slightly less than 18 percent of all observations. Approximately 74 percent of state/year observations had an ALR policy in place while approximately a third of all observations had a BAC limit of 0.08 or less during the period of analysis. During the late

[10] To conserve space, we do not report the estimated coefficients for the control variables nor the state and year fixed effects. These results can be obtained upon request and can be found in French et al. (2008).

1990s, several states adopted more stringent traffic safety policies by implementing mandatory rider education programs and stricter BAC limits while other states repealed their mandatory universal helmet policy and raised their maximum speed limit.

The estimation results for core models are presented in Table 2. We report the estimated coefficients together with their standard errors in parentheses. All specifications in this table include state and year fixed-effects. In the first two columns, we present the results of the fixed-effects linear model for non-fatal injury rates. The first column includes alcohol and traffic policies and motorcycle registrations per 100,000 people, without any other control variables. The second column presents the estimation results when a rich set of state-specific control variables is added to the analysis. Note that the inclusion of state-specific controls does not alter the main results in this analysis. All three traffic safety policies are significantly related to non-fatal injury rates. Mandatory rider education programs reduce non-fatal injuries by approximately 10 percent ($p < 0.01$). The estimated effect of universal helmet laws is even larger, decreasing the non-fatal injury rate by approximately 20 percent ($p < 0.01$). Paradoxically, a 10 mph reduction in the speed limit would increase the non-fatal injury rate by about 11 percent ($p < 0.01$). It is possible that traveling at higher speeds makes avoiding a motorcycle crash more difficult and, if a crash occurs, may lead to a fatal rather than a non-fatal injury. It could also be the case that more rural states, with less vehicular traffic and associated hazards, are more likely to raise speed limits. Zero tolerance laws and a .08 BAC limit are not significantly associated with non-fatal injuries whereas ALR laws work in the opposite direction from our hypothesis.

Columns 3 and 4 in Table 2 present the linear fixed-effects results with the fatality rate per 100,000 people as the dependent variable. As discussed above, modeling fatalities as a count rather than a rate may be more appropriate, so we refrain from drawing any conclusions in terms of the quantitative results. This specification, however, allows us to make direct qualitative comparisons between fatal and non-fatal injury estimates. A universal helmet law is the only public policy that significantly influences the rate of motorcycle fatalities. The estimated coefficient on the ALR policy is positive (and statistically significant) in the non-fatal injury models, but essentially zero in the fatal injury models. One possible explanation for the differential effect of ALR in the non-fatal and fatal injury models could be that the severity, reporting, and other characteristics of non-fatal crashes are important omitted variables. If adopting policies such as the ALR reduces the overall severity of crashes, but not the frequency, then it could be that relatively more traffic crashes will lead to non-fatal injuries rather than fatal ones. In fact, both passenger car fatalities and overall motor vehicle fatalities are on average higher for state and year observations without an ALR policy in place.

The results of the conditional fixed-effects negative binomial models for the count of fatal motorcycle injuries are presented in columns 5 and 6 of Table 2. We report the estimated coefficient, estimated standard error (in parentheses), and the associated incidence rate ratios (IRR [in brackets]) for each explanatory variable.[11] Statistical significance is based on a test of the null hypothesis that there is no relationship between motorcycle fatalities and the explanatory variable (i.e., IRR is equal to 1). The results from this model are consistent with those in columns 3 and 4, which show a strong negative effect of universal helmet laws on motorcycle fatalities. None of the other alcohol or traffic policies are statistically significant in columns 5 and 6.[12]

As seen in all specifications, a universal helmet law significantly reduces both fatal and non-fatal injuries ($p < 0.01$). Although our results for non-fatal injuries are unique, these estimates are consistent with the findings of previous studies, showing a significant negative relationship between universal helmet laws and motorcycle fatalities. Sass and Zimmerman (2000) estimated that universal helmet laws lower per capita motorcyclist fatalities by about 24 percent. Houston and Richardson (2008) concluded that states with universal helmet laws had rider fatality rates that were about 29 percent lower than states without universal policies. More recent estimates by Dee (2009) reveal similar effects of universal helmet laws on motorcyclist fatalities (27 percent). Our estimates indicate that over the period from 1990 to 2005, universal helmet laws led to a 24 (20) percent reduction in fatal (non-fatal) motorcycle injuries.

In 2005, 20 of the 48 states in our sample had universal helmet laws. Total rider fatalities were 1894 for universal helmet law states and 2472 for states without a universal helmet law. Based on the estimates from our models and additional calculations, about 489 lives could have been saved if universal helmet laws had been in effect in all 48 states. Using $5 million as the value of a statistical life (Viscusi and Aldy, 2003), the estimated mortality cost associated with the absence of universal helmet policies in 2005 alone was almost $2.5 billion. It would be interesting to determine whether motorcyclists would be willing to pay an “endorsement fee” each year for the right to ride without a helmet, which could offset some of these costs, but such a cost–benefit analysis is beyond the scope of the present paper.

To further examine the sensitivity of the results to model specification, we conducted several robustness checks.[13] First, we re-estimated the specifications in columns 5 and 6 of Table 2 using a conditional fixed-effects Poisson model instead of a negative binomial model. In each case, the results were virtually identical. Next, we disaggregated the total fatality counts according to the day or the time of the crash. One might expect the alcohol policies to have a relatively larger effect on nighttime and weekend fatalities than on daytime and weekday fatalities. The rationale here is that such policies would influence drinking behaviors more at night and on weekends when alcohol consumption is more common. On the contrary, the results are similar (both qualitatively and quantitatively) for all specifications, regardless of the time or day. Finally, in an effort to identify whether the alcohol and traffic policies have similar effects on drivers other than motorcyclists, we estimated separate regressions for motorcycle rider fatalities in single-vehicle crashes and rider fatalities in multi-vehicle crashes involving at least one motorcycle and one other type of vehicle. Once again, the stratified results are consistent with our core models and do not reveal any evidence of differential policy effects.

Given the limited within-state variation in alcohol taxes over time for most states, the beer tax was not included in our core specifications. As an additional robustness check, we re-estimated the

[11] IRRs are the exponentiated coefficients and represent the difference in the rate of fatalities predicted by the model when the variable of interest is increased by one unit above its mean value while all other variables are kept constant at their means (see Table 1 of French et al. (2008) for the means and units of measure for all variables used in the analysis). A value greater than 1 indicates a positive relationship between the rate of fatalities and the particular regressor, and a value less than 1 indicates the opposite.

[12] Despite the fact that we control for the number of motorcycle registrations in the conditional fixed-effects negative binomial models, some of the policies we consider might indirectly reduce motorcycle-related fatalities by discouraging motorcycling in general. A closer examination of motorcycle registrations per capita indicates a negative relationship with universal helmet laws. This suggests that states that adopt universal helmet laws might inadvertently reduce motorcycle-related fatalities by reducing motorcycle usage.

[13] The full results of the sensitivity analyses are available upon request from the corresponding author.

core models with the beer tax. Coefficient estimates on all other alcohol and traffic policies are virtually unchanged in terms of sign, magnitude, and significance. While the results consistently indicate that the beer tax has a negative and significant impact on motorcycle fatalities, we are not confident in the large estimated magnitude of this effect.[14] The beer tax coefficient is not significant in our fully augmented non-fatal injury specification, and we are not aware of any studies that have estimated the effect of the beer tax on non-fatal automobile injuries. In light of concerns about the magnitude of the beer tax estimates reported in other studies and the possibility that beer taxes are correlated with important unobservable factors, we decided to exclude this measure from our core specifications in Table 2. Finally, we added per capita beer consumption to the models to examine whether controlling for state-specific patterns in alcohol consumption might alter the main findings. As expected, per capita beer consumption is positively and significantly related to both fatal and non-fatal injuries, but inclusion of this variable does not meaningfully change the estimated effects of the alcohol and traffic policies.

6. Conclusion

To our knowledge, this study is the first rigorous longitudinal analysis of the effects of public policies on both fatal and non-fatal motorcycle crashes in the U.S. Using state-specific data from 1990 to 2005, our findings suggest that several public policies can significantly reduce non-fatal motorcycle injuries, including mandatory rider education programs, universal helmet laws, and lower speed limits on rural interstates. On the other hand, universal helmet laws seem to be the most reliable and effective policy tool to reduce fatal motorcycle injuries.

The primary objective of this study was to determine the effects of alcohol and traffic policies on motorcycle safety, but we also considered a large set of demographic, economic, and environmental controls, as these important state characteristics could influence motorcycle crashes as well. An extensive data collection effort from a variety of sources was required to compile state-specific information on non-fatal injuries, alcohol and traffic policies, and the rich set of controls. Data on non-fatal injuries among motorcyclists were collected from unpublished state-specific documents, archived data files, and personal correspondence. Information on non-fatal injuries was not available for all years and states. In addition, data collection resources and procedures might differ slightly across states. Any potential measurement error, if present, would bias the results to the extent it is systematically correlated with the policy changes over time. A standardized source of data on non-fatal injuries for all states and years (similar to FARS) would have considerably reduced data collection costs and research time and improved overall reliability of the estimates.

As in most studies of motor vehicle safety, there are additional limitations to our empirical analysis. First, data were unavailable for some potentially important predictors in our models, such as annual motorcycle miles traveled. Furthermore, the estimates could be biased due to endogenous policy adoption. We believe, however, that our estimates for policies targeting all motor vehicle drivers (e.g., ALR) are less likely to be endogenous than those specifically targeting motorcycle riders (e.g., universal helmet laws). Finally, the inclusion of state and time fixed-effects cannot compensate for important omitted variables that vary within states over time. Some potentially important time-varying omitted variables include policy enforcement and grass-roots activities by Mothers Against Drunk Driving (MADD), American Bikers Aiming Toward Education (ABATE), or other advocacy groups (Eisenberg, 2003).

Despite these limitations, this study is original, timely, and policy relevant given the dramatic rise in the popularity of motorcycle riding and the recent volatility of gasoline prices that is encouraging motorists to switch to fuel-efficient vehicles. Studies investigating motor vehicle safety and public policy have largely focused on automobiles and trucks and almost exclusively on fatal injuries. Public policy in this area should also be evaluated in terms of its effectiveness in reducing non-fatal injuries, which occur far more frequently and generate high social costs. Given that many motorcyclists misunderstand or simply disregard the increased safety risks relative to operating an automobile (Bellaby and Lawrenson, 2001), these individuals may be reluctant to abandon their dangerous riding behaviors and may underestimate the value of safety programs. Our findings suggest that certain public policies can significantly impact motorcycle safety, and, with the exception universal helmet laws, differential effects are present for fatal and non-fatal injuries.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at doi:10.1016/j.jhealeco.2009.05.002.

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[14] A few studies have offered explanations for why an increase in the beer tax can be quite effective in reducing automobile fatalities even though these taxes display only small within-state variations over time (Dee, 1999; Mast et al., 1999; Dee and Evans, 2001; Young and Bielinska-Kwapisz, 2006). The most plausible explanation is that beer taxes are correlated with other important and omitted state-level characteristics such as law enforcement, health policies, or social and political attitudes towards alcohol.

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