Generalized linear regression analysis of association of universal helmet laws with motorcyclist fatality rates

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Abstract

This study evaluates the association of universal helmet laws with U.S. motorcyclist fatality rates from 1993 through 2002 using climate measures as statistical controls for motorcycling activity via quasi-maximum likelihood generalized linear regression analyses. Results revealed that motorcyclist fatalities and injuries are strongly associated with normalized heating degree days and precipitation inches, and that universal helmet laws are associated with lower motorcyclist fatality rates when these climate measures, and their interaction, are statistically controlled.

This study shows that climate measures have considerable promise as indirect measures (proxies) of motorcycling activity in generalized linear regression studies.

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1. Introduction

According to the National Center for Statistics and Analysis (NCSA) of the National Highway Traffic Safety Administration (NHTSA), recent data indicate that only about half of all fatally injured motorcyclists in the United States were wearing helmets (NCSA, 2001). While there is evidence that wearing a compliant motorcycle helmet reduces the likelihood and severity of severe head injury and death (Deutermann, 2004; NCSA, 1996; NHTSA, 2003a; Sass and Zimmerman, 2000), several states have recently relaxed motorcycle helmet laws, and helmet use has declined (NCSA, 2002). At the end of 2002, only 20 states had a universal helmet law requiring that all motorcyclists wear helmets; the remaining states, except for three, had laws requiring that some riders wear helmets (NHTSA, 2003b). States with a universal helmet law require all motorcycle riders to wear helmets at all times while riding on public roads. Most states without a universal helmet law still require some riders to wear helmets, e.g. riders under 15, 18, 19, or 21; riders with an instruction permit or less than 1 year of experience; riders who have not completed a training course; riders without US$ 10,000 of medical insurance, etc. During the 10-year period from 1993 through 2002, 25 states never had a universal helmet law, 20 states always had a universal helmet law, and five states started with a universal helmet law but eliminated it during that decade (NCSA, 1993–2002).

To evaluate the effectiveness of universal helmet laws, one approach is to compare motorcyclist fatalities in states with a universal helmet law to those in states without it, adjusting for differences in motorcyclist activity between the states. Unfortunately, while the number of motorcycle registrations is available for individual states, the number of motorcycle miles traveled is not. Although the number of motorcycle registrations is partially related to exposure, this measure neglects variation in the amount of activity of the registered motorcycles—a key quantitative measure needed to assess the association of fatality rates with helmet laws. However, since motorcycle activity is highly seasonal, with more activity on warm or dry days than on cold or rainy days, and climates vary markedly across states in the U.S., fatalities per registered motorcycle can be compared between states with and without universal helmet laws while controlling for climate measures correlated with motorcyclist activity.

In a careful study with controls for various factors known or expected to be associated with motorcyclist fatality rates, such as average temperature, precipitation, population density, alcohol use, speeding, and engine size, Branas and Knudson (2001)
found no significant difference in fatality rates between states
with versus without universal helmet laws from 1994 through
1996. While their findings demonstrate the importance of sta-
tistical controls in the comparison of state fatality rates, the null
results raise questions about the statistical power of their study
and leave open the question of a potential benefit of univer-
sal helmet laws. In a panel study spanning the 22 years from
1976 to 1997, Sass and Zimmerman (2000) reported an average
29–33% decrease in per capita motorcyclist fatalities associated
with state laws mandating helmet use by motorcyclists. They
also found similar results in a set of 22 separate cross-sectional
single-year analyses. Of many interesting features of their study,
one was the use of a climate measure, heating degree days, as
both an indirect measure of motorcyclist activity as well as a fac-
tor thought to interact with motorcycle helmet usage (i.e. with
more helmet usage in states with harsher climates). Their study
also included many other factors in complex structural models,
some of which simultaneously estimated over 80 parameters
under strict covariance assumptions required by panel studies.
While the strict covariance assumptions of panel studies are irre-
levant to model parameter estimates, violation of the assumptions
causes underestimation of standard errors of the parameter esti-
mates, making the true likelihood of erroneously rejecting null
hypotheses much greater than the nominal (α) levels. Unfortu-
nately, as noted by Sass and Zimmerman (2000, p 208), the
available tests of such assumptions often lack sufficient power
to reliably detect violations.

An association of state universal helmet laws with reduced
state fatality rates is likely to be hard to detect statistically
for several reasons: all but three states require at least some
riders to wear helmets; some riders wear helmets even when
they are not legally required; motorcyclist fatalities are not only
attributable to head injuries; many factors influence motorcy-
clist fatalities; and direct motorcyclist activity data do not exist.
Statistical power – the likelihood a study will detect an existing
association – is an increasing function of both the proportion
of variance explained by a set of explanatory variables and the
degrees of freedom for the model; however, while increasing the
number of linearly independent explanatory variables increases
the proportion of explained variance (with diminishing returns),
it also decreases the degrees of freedom (with an accelerated
effect the fewer the degrees of freedom)—which with only the
50 independent (multivariate) observations available for U.S.
state comparisons, quickly costs more statistical power than is
 gained by additional explanatory variables.

Since climate measures are strongly associated with motorcy-
clist activity, the strongest factor associated with fatality risk, the
present study examines the association of universal helmet laws
with motorcyclist fatality rates using pertinent climate measures
to control for motorcyclist activity in quasi-maximum likeli-
hood generalized linear regression analyses. While the states
undoubtedly still differ in minor ways aside from climates and
the presence or absence of universal helmet laws, the multitude
of such independent minor factors mitigates against the likeli-
hood of severe bias attributable to them. The analytic objective is
to maintain scientific parsimony and statistical power, with min-
imal reliance on stringent statistical assumptions, by modeling
fatality rates as a function of one explanatory variable (universal
helmet law) and two climate-related activity measures (heating
degree days, precipitation) along with pertinent quadratic and
interaction terms. Quasi-maximum likelihood generalized lin-
ear modeling provides crucial flexibility in modeling the relation
between a function of the mean and the covariates, the relation
between the mean and variance, and the error distribution.

2. Methods

Motorcyclist fatality data are from NHTSA's Fatality
Analysis and Reporting System (FARS-NCSA, 2005). FARS
is a database of information about the scenarios, vehicles,
drivers, and passengers involved in all fatal motor vehicle
crashes on public highways and roads in the U.S. Data on
hospital emergency room-treated injuries are from the U.S.
Consumer Product Safety Commission's (CPSC) National
Electronic Injury Surveillance System-All Injury Program
(NEISS-AIP) (Schroeder and Ault, 2001). Data on number of
registered motorcycles by states are from the Federal Highway
Administration (FHWA, 1992–2002).

Normalized state climate data, including population-
weighted annual heating degree days and precipitation inches,
are from the National Oceanic and Atmospheric Administration
(NOAA-NCDC, 2002a,b). The heating degree days statistic is a
measure of cold weather energy consumption and is defined as
the annual sum of daily differences in mean daily temperature
from a 65 °F base (with the difference set to 0 if the mean daily
temperature exceeds the 65 °F base temperature), averaged across
all stations within the state, with the average weighted by popu-
lation distribution in the area. At one station in a given year, for
example, 5 days with a mean daily temperature of 64 °F would
result in 5 degree days, as would 1 day with a mean daily temper-
ature of 60 °F. NOAA's normalized heating degree day measure,
an annual average derived over the 30-year period 1971–2000,
is a climate measure that estimates the annual average heating
degree days for each state during the normalization period. The
advantage of heating degree days over average temperature as
a measure of motorcyclist activity consists both in its theoreti-
cal utility for ratio-scale measurement of the change in thermal
energy necessary to maintain a comfortable ambient temperature
and in its empirical utility in accounting for substantial nuisance
variation in fatality rates.

For each state, the annual average fatality rate was estimated
by dividing the sum of fatalities across the decade from 1993
to 2002 by the sum of motorcycle registrations each year across
the same period. The annual average heating degree days and
precipitation were obtained likewise.

Generalized linear regression analysis compared fatality rates
in states with and without universal helmet laws adjusting for
exposure as indexed by normalized state climate data. To include
all 50 states in the present analysis, the five states that repealed a
universal helmet law sometime during the decade of 1993–2002
(three in 1997, one in 1999, and one in 2000) were grouped with
states that never had a universal helmet law during that decade.
Also, following NOAA, data for the District of Columbia were
combined with those for Maryland, both of which had a universal
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