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Latent class analysis of the effects of age, gender, and alcohol consumption on driver-injury severities

Ali Behnood *, Arash M. Roshandeh, Fred L. Mannering [1]

Lyles School of Civil Engineering, Purdue University, 550 Stadium Mall Drive, West Lafayette, IN 47907-2051, USA

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ABSTRACT

This study explores the differences in driver-injury severity between drivers impaired and not-alcohol-impaired, while taking into consideration the role of age and gender. Using data from single-vehicle crashes from Illinois' Cook County over an eight-year period from January 1, 2004 to December 31, 2011, separate alcohol-impaired and not-alcohol-impaired models of driver-injury severity (with possible outcomes of no injury, minor injury, and severe injury) were estimated for younger male, older male, younger female, and older female drivers (those younger than 31 years old were considered younger drivers, and those 31 years old and older were considered older drivers). In addition to considering driver age, alcohol condition, and gender, a wide range of variables potentially affecting crash severity was considered, including a number of variables relating to highway attributes, vehicle characteristics, and environmental conditions. Using a latent class multinomial logit modeling approach to capture unobserved heterogeneity, estimation results show that there were substantial differences across age/gender groups in the absence/presence of alcohol. In addition, among others, particularly complex relationships were uncovered with regard to the impact of alcohol consumption, safety-belt effectiveness, roadway type, distracted driving, vehicle occupancy, and the effects of airbag deployment on injury severity.

1. Introduction

It has long been established that adverse driver behavior, including behavior relating to distracted driving, propensities for risk taking, and driving under the influence of alcohol or drugs, have been critical determinants with regard to the likelihood of a vehicle crash and its resulting injury severity. In fact, there have been numerous studies that have sought to provide insights into the propensity of drivers to engage in risky behaviors (Brandau et al., 2011; Constantinou et al., 2011; Jakubczyk et al., 2013). Of all of the risky-driving behaviors, driving under the influence of alcohol is widely acknowledged as one of the most dangerous (Mann et al., 2010; NHTSA, 2005). This worldwide problem has led to seemingly countless injuries and loss of life. For example, in the U.S., the number of people who died in alcohol-impaired driving crashes in 2012 accounted for an astonishing 31% of all fatalities (NHTSA, 2013). And, in Taiwan, nearly 60% of fatally-injured drivers and 40% of fatally-injured motorcyclists were under the influence of alcohol (Huang and Lai, 2011).

* Corresponding author.
E-mail addresses: abehnood@purdue.edu (A. Behnood), aroshand@purdue.edu (A.M. Roshandeh), flm@ecn.purdue.edu (F.L. Mannering).
[1] Fax: +1 765 494 0395.

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While the overall negative effects of driving under the influence of alcohol have been well established from countless studies, there are many subtleties that are not fully understood such as the effect of crash location, environmental factors, gender differences, age, and so on (Schlotthauer et al., 2011; Christoforou et al., 2013; Alcañiz et al., 2014). For example, with regard to crash location, a study of vehicle crashes in California by Khorashadi et al. (2005) found that when alcohol/drug use was identified as the primary cause of a crash the likelihood of fatal injury increased by roughly 250% in rural areas and nearly 800% in urban areas. In other work, Czech et al. (2010) found that the rate of alcohol-related crashes in Australia (per unit population) was 1.5 times higher in rural communities relative to urban communities. These findings suggest considerable variability in the effect of alcohol on crashes, and gaining a better understanding of the factors that contribute to this variability could potentially help to guide safety policies.

In the current paper, we are interested in specifically studying the effects of age, gender and alcohol involvement on driver-injury severities in single-vehicle crashes, while controlling for a wide-range of factors such as crash location, airbag deployment, initial crash impact point on the vehicle, roadway characteristics, safety-belt use, time of day, weather conditions, and so on. With regard to age and gender, an abundance of past research has clearly shown that injury severities vary significantly between males and females and across different age groups as various driver behavior, accumulated experience, and risk-taking are known to vary among these classifications (Richardson et al., 1996; Awadzi et al., 2008). To address this possibility in injury-severity models, there have been several recent studies that have sought to isolate the specific determinants of injury-severities by estimating separate statistical models on gender/age sub-sets of the available injury data. From an econometric perspective, the estimation of separate models on sub-populations of the data allows one to uncover potentially important relationships between explanatory variables and injury severities that may otherwise be missed in traditional statistical modeling.[2] In past work for example, Islam and Mannering (2006) estimated separate injury-severity models for three different age groups and both genders (six different models), finding that the gender/age group combinations produced significantly different results implying that the effects of various explanatory variables were statistically different across age-group/gender combinations. Later, Morgan and Mannering (2011) estimated separate driver-injury severity models by considering gender differences with two age groups and three different types of pavement conditions (wet, dry, snow/icy) for a total of twelve different models and they again found significantly different explanatory-variable effects across sub-sets of the population.[3]

Adding alcohol involvement as a factor for distinguishing subsets of the data offers a potentially interesting new dimension to the study of driver-injury severities because the effect of alcohol involvement on injury severities, and how its effect varies over gender/age groups, has not been fully explored to date. Unlike the probability of crash occurrence, where alcohol involvement for all age/gender groups would be expected to unambiguously increase the probability of crash (although quite likely at varying rates), the effect of alcohol involvement on injury-severity is more complex. For example, alcohol involvement is likely to impair judgment such that the driver may be less able to implement mitigating actions (such as braking and steering). In the absence of such actions (or the implementation of incorrect actions in an alcohol-impaired state) one would expect higher impact speeds and thus more severe injuries. In contrast to this, some research has shown that intoxicated individuals are more relaxed at impact and this can distribute impact forces over larger areas of the body potentially reducing the injury severity of the crash. In fact, for certain types of brain trauma, intoxication has been associated with reduced hospital stays and injury-mortality rates (Salim et al., 2009; Hsieh et al., 2013). While the overall aggregate data show that the effect of alcohol involvement is clearly correlated with increased injury severity, there is evidence to suggest that the relationship between alcohol involvement and injury severity is complex, and likely to vary considerably across age and gender groups.

2. Methodology

Many research efforts have been undertaken to study vehicle-injury severities using variety of methodological approaches including multinomial logit models, dual-state multinomial logit models, nested logit models, ordered probit models, Markov switching ordered probit models, latent-class logit models, mixed logit models, and others (see Savolainen et al. (2011) and Mannering and Bhat (2014) for injury-severity methodology reviews). Much of the current front-line research on injury severities has used random parameters (Eluru et al., 2008; Milton et al., 2008; Morgan and Mannering, 2011; Anastasopoulos and Mannering, 2011; Kim et al., 2013; Haleem and Gan, 2013; Cerwick et al., 2014), latent class models (Yasmin et al., 2014; Shaheed and Gkritza, 2014; Cerwick et al., 2014), or both (latent class with random parameters with each class, see Xiong and Mannering, 2013) to account for unobserved heterogeneity across the injury-severity observations.

Herein, driver-injury severities are studied in single-vehicle crashes using latent-class multinomial logit models, which can account for possible unobserved heterogeneity by identifying unobserved (to the analyst) classes in the population. This

[2] Random parameters and latent class models have been applied in the past to crash-injury severity modeling in attempt to avoid the restriction that traditional statistical methods impose by estimating a single parameter for each explanatory variable across the population. See Mannering and Bhat (2014) for a discussion of these approaches.

[3] Unlike previous studies that have considered sub-sets of the crash-injury data, Morgan and Mannering (2011) used random parameters models of injury severity which can account for unobserved heterogeneity across observations within each age/gender/road-condition sub-population.