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A latent class analysis of single-vehicle motorcycle crash severity outcomes

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ABSTRACT

Unobserved heterogeneity has been recognized as a critical issue in traffic safety research that has not been completely addressed or often overlooked, and can lead to biased estimates and incorrect inferences if inappropriate methods are used. This paper uses a latent class approach to investigate the factors that affect crash severity outcomes in single-vehicle motorcycle crashes. Motorcycle crash data from 2001 to 2008 in Iowa were collected with a total of 3644 single-vehicle motorcycle crashes occurring during that time period. A latent class multinomial logit model is estimated that addresses unobserved heterogeneity by identifying two distinct crash data classes with homogeneous attributes. The estimation results show a significant relationship between severe crash injury outcomes and crash-specific factors (such as speeding, run-off road, collision with fixed object and overturn/rollover), riding on high-speed roads, riding on rural roads, riding on dry road surface, riding without a helmet, age (riders older than 25 years old) and impaired riding (riders under the influence of drug, alcohol or medication). The model fit and estimation results underline the need for segmentation of crashes, and suggest that the latent class approach can be a promising tool for modeling motorcycle crash severity outcomes.

1. Introduction

In the United States (U.S.), motorcycle registrations increased by 67% during the period from 2001 to 2010. However, motorcycles still constitute a small subset of the total registered motor vehicles, which makes up around 3% (National Highway Traffic Safety Administration, 2012). Despite their small share of vehicle registrations, motorcycles are over-represented in fatal crashes in the U.S. (Preusser et al., 1995). According to the National Highway Traffic Safety Administration (2012), motorcycle crash fatalities have been increasing each year in the U.S. from a historic low of 2116 fatalities in 1997 to as high as 5312 fatalities in 2008. In 2010, motorcyclists accounted for 14% of total traffic fatalities, although motorcycles accounted for only 0.6% of all vehicle miles traveled (National Highway Traffic Safety Administration, 2012). Similarly in the state of Iowa, motorcycle registrations increased by 41.4% from 2001 to 2010. Motorcycle fatalities in Iowa increased from 38 in 2001 to the highest of 61 in 2007, with motorcycle registrations increasing by 27% during that period.

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Among the types of crashes involving motorcycles, single-vehicle motorcycle crashes have accounted for almost 50% of the total riders killed in both single- and multi-vehicle motorcycle crashes from 2001 to 2010 (National Highway Traffic Safety Administration, 2012). Previous research has asserted that single- and multi-vehicle crashes are best described when modeled separately (Geedipally and Lord, 2010).

Furthermore, some of the factors affecting the severity of motorcycle crashes are not observable, or relevant information is not reported by law enforcement agencies and cannot be collected from state crash records. Such information includes motorcycle speed, motorcycle size, riders' physical health, riders' experience and training. Therefore, heterogeneity may arise from these unobserved factors when developing motorcycle crash severity models as a function of observed factors, resulting in biased parameters and incorrect inferences (Mannering and Bhat, 2014). To overcome this problem, this paper uses a latent class approach to investigate the factors and their effect on single-vehicle motorcycle crash severity outcomes.

2. Literature review

Extensive research has been conducted on investigating the risk factors and patterns associated with single-vehicle motorcycle crashes. Mannering and Grodsky (1995) stated that since riding a motorcycle is generally recognized as a dangerous activity, it may tend to attract risk-seeking individuals, regardless of their age or their socioeconomic background. Risky driving behaviors, such as speeding or drinking and riding, can significantly affect the severity outcome of a crash. For instance, Shankar and Mannering (1996) found that speeding increases the likelihood of fatal or injury outcomes using single-vehicle motorcycle crash data in the state of Washington. Similar results are also reported in Savolainen and Mannering (2007) that examined crash data in Indiana. Past studies also have shown that motorcycle engine size is associated with motorcycle crash injury severity outcomes (de Lapparent, 2006; Harrison and Christie, 2005; Lin et al., 2003; Mullin et al., 2000; Pai and Saleh, 2007; Quddus et al., 2002; Savolainen and Mannering, 2007; Sexton et al., 2004).

Age and gender are among the most important rider-specific factors that affect both frequency and severity of motorcycle crashes. Previous research found that the likelihood of fatality and disabling injury in single-vehicle motorcycle crashes increases with increasing motorcycle rider age (Nunn, 2011; Pai and Saleh, 2007; Quddus et al., 2002; Savolainen and Mannering, 2007; Shankar and Mannering, 1996). The finding that older motorcyclists are more likely to be severely injured could be attributed to the slower reaction time and reduced sensory and perceptual ability, as well as to the decreased physical resiliency to motorcycle crashes compared to younger drivers (Pai and Saleh, 2007; Savolainen and Mannering, 2007).

Survey-based studies (Lin et al., 2003; Mullin et al., 2000) revealed that experience of the riders was an important risk factor associated with motorcycle crashes. Harrison and Christie (2005) found that riding patterns, skill acquisition, and training are important risk factors associated with motorcycle crashes. Other risk factors include a temporary break from riding and lack of basic training (Sexton et al., 2004). Note that these factors are usually not available in police-reported crash databases. Results of past research, as summarized in Lin and Krauss (2009), suggest that motorcycle riders are more likely to drink and ride compared to other motor-vehicle drivers. In the U.S., alcohol-related fatal motorcycle crashes are higher than alcohol-related fatal crashes involving other types of vehicles (National Highway Traffic Safety Administration, 2008).

The effectiveness of helmet use has been investigated extensively in the literature. Past work summarized in Lin and Krauss (2009), argued that helmet use reduced the risk of motorcycle deaths by 29% in the U.S. during the period 1972–1987. Based on the results of past studies in the U.S., it has been suggested that non-helmeted riders are more likely to die, incur head injuries, or require longer hospitalization compared to helmeted riders. Comprehensive helmet laws also have been associated with an increase in helmet use followed by a decrease in the number of motorcycle fatalities and head injuries (Houston, 2007; Lin and Krauss, 2009).

Road type and geometry along with roadside installations, pavement surface conditions, lighting and visibility conditions, and manner of crashes (such as run-off road, collision with stationary object or other) constitute another group of risk factors (Vlahogianni et al., 2012). With regards to lighting and visibility conditions, poor visibility due to horizontal or vertical curvature or darkness has been associated with an increase in motorcycle injury severity (Savolainen and Mannering, 2007). Turning to the type of collision, research has shown that collisions with stationary objects result in more severe injuries (Quddus et al., 2002; Savolainen and Mannering, 2007). Riding on wet roadway surface can be a risk factor as well; however, the crash risk may be mitigated, especially if motorcyclists maintain lower speed due to the poor surface condition (Savolainen and Mannering, 2007).

3. Methodological background

This section discusses the modeling techniques that have been employed in the past to estimate motorcycle crash severity outcomes. Shankar and Mannering (1996) applied a multinomial logit model to estimate the factors affecting single-vehicle motorcycle crash severity. Quddus et al. (2002) estimated ordered probit models to examine motorcycle damage and injury severity resulting from motorcycle crashes. Savolainen and Mannering (2007) estimated both nested logit and multinomial logit models to analyze single- and multi-vehicle motorcycle crashes in Indiana. Chimba and Sando (2010) applied multinomial logit and multinomial probit models to identify the factors associated with motorcycle crash injury severities in Florida. Rifaat et al. (2012) estimated an ordered logit model, a heterogeneous choice model, and a partially constrained generalized ordered logit model to