Analytic Methods in Accident Research 2 (2014) 21–29

Contents lists available at ScienceDirect

Analytic Methods in Accident Research

journal homepage: www.elsevier.com/locate/amar

Comparison of factors affecting injury severity in angle collisions by fault status using a random parameters bivariate ordered probit model

Brendan J. Russo[a,1], Peter T. Savolainen[a,*], William H. Schneider IV[b,2], Panagiotis Ch. Anastasopoulos[c,3]

[a] Department of Civil and Environmental Engineering, Wayne State University, 5050 Anthony Wayne Drive, EDC 0504.01, Detroit, MI 48202, USA
[b] Department of Civil Engineering, The University of Akron, Auburn Science and Engineering Center, Room 210, Akron, Ohio 44325, USA
[c] Department of Civil, Structural and Environmental Engineering, Institute for Sustainable Transportation and Logistics, University at Buffalo, The State University of New York, 241 Ketter Hall, Buffalo, New York 14260, USA

ARTICLE INFO

Article history:
Received 30 November 2013
Received in revised form
10 March 2014
Accepted 10 March 2014
Available online 19 April 2014

Keywords:
Crash severity
Intersection crash
Fault status
Random parameter bivariate ordered probit

ABSTRACT

The extant traffic safety research literature includes numerous examples of studies that assess those factors affecting the degree of injury sustained by crash-involved motor vehicle occupants. One important methodological concern in such work is the potential correlation in injury outcomes among occupants involved in the same crash, which may be due to common unobserved factors affecting such occupants. A second concern is unobserved heterogeneity, which is reflective of parameter effects that vary across individuals and crashes. To address these concerns, a random parameters bivariate ordered probit model is estimated to examine factors affecting the degree of injury sustained by drivers involved in angle collisions. The modeling framework distinguishes between the effects of relevant factors on the injury outcomes of the at-fault and not-at-fault parties. The methodological approach allows for consideration of within-crash correlation, as well as unobserved heterogeneity, and results in significantly improved fit as compared to a series of independent models with fixed parameters. While the factors affecting injury severity are found to be similar for both drivers, the magnitudes of these effects vary between the at-fault and not-at-fault drivers. The results demonstrate that injury severity outcomes are correlated for drivers involved in the same crash. Further, the impacts of specific factors may be over- or under-estimated if such correlation is not accounted for explicitly as a part of the analysis. Various factors are found to affect driver injury severity and the random parameters framework shows these effects to vary across crashes and individuals. The analytical approach utilized provides a useful framework for injury severity analysis.

* Corresponding author. Tel.: +313 577 9950; fax: +313 577 8126.
E-mail addresses: brendan@wayne.edu (B.J. Russo), savolainen@wayne.edu (P.T. Savolainen), whs4@uakron.edu (W.H. Schneider IV), panastas@buffalo.edu (P.Ch. Anastasopoulos).
[1] Tel.: +313 577 8228; fax: +313 577 8126.
[2] Tel.: +330 972 2426.
[3] Tel.: +716 645 4362.

http://dx.doi.org/10.1016/j.amar.2014.03.001
2213-6657/

1. Introduction

Although traffic crashes, injuries, and fatalities in the United States have been trending downward in recent years, in 2010 alone there were 23,303 motor vehicle occupant fatalities and 2,027,000 injuries (NHTSA, 2012). According to the National Safety Council (2010), each crash-related fatality results in an average economic cost of $1,410,000 while each non-fatal disabling injury costs society $70,200. The true costs of traffic crash injuries and fatalities are even greater as these economic costs do include measures such as lost quality of life. Gaining a better understanding of the factors that affect the degree of injury sustained by crash-involved occupants is critical in developing methods for addressing this public health issue.

Angle collisions are among the most severe crashes in terms of injury outcomes. These crashes typically occur at intersections or driveways when one of the crash involved drivers fails to yield or disregards a traffic control device. In 2010, these types of collisions represented 36.1% of all motor vehicle crashes (NHTSA, 2012). During this same period, angle collisions represented 50.7% of fatal crashes and 41.1% of injury crashes, illustrating the clear need for a careful examination of the factors associated with such crashes. In angle crashes, one party is generally found to be at fault and the relationship between fault status and injury outcomes is of general interest to the traffic safety community. While some prior research has investigated factors associated with fault status designation (Haque et al., 2009; Jiang et al., 2012; Kim et al., 2008; Schneider et al., 2012; Ulfarsson et al., 2010), research on the effects of fault status on injury outcomes is quite limited. Savolainen and Mannering (2007) found that motorcyclists who were at-fault were more likely to be fatally injured; however, other studies have shown mixed results with respect to fault status and injury outcomes (Abdel-Aty, 2003; Helai et al., 2008). The analysis of injury severity data from angle crashes is complicated by several factors, including the potential correlation in injury outcomes among occupants involved in the same crash.

In this study, injury severity data are examined from angle crashes occurring at intersections in the state of Michigan. A random parameters bivariate ordered probit (RPBOP) model is developed to jointly examine the degree of injury sustained by each crash-involved driver. The use of the RPBOP model allows for consideration of within-crash correlation while the estimation of random parameters allows for the effects of variables to vary across observations. The injury severity levels of the at-fault and not-at-fault drivers are estimated separately, such that differential effects of each independent variable can be identified.

2. Literature review

Numerous studies have examined factors that affect crash injury severity. The broad body of existing research covers a wide array of topics and analytical techniques. Generally, such studies focus on a specific crash type, vehicle type, or roadway type. Findings from these studies can provide valuable insights into factors that affect injury outcomes, though these results may not be applicable to all traffic crash scenarios. Savolainen et al. (2011) provide a summary of methodological issues encountered when analyzing crash severity data, as well as an overview of statistical techniques that have been used in analyzing such data. Commonly applied statistical models include multinomial logit models, ordered logit and probit models, and random parameter (mixed) logit models.

O'Donnell and Conner (1996) estimated ordered probit and ordered logit models to examine factors affecting injury severity for all crash types and all locations occurring in New South Wales, Australia. Kockelman and Kweon (2002) investigated driver injury severity by estimating separate ordered probit models for single-vehicle crashes and two-vehicle crashes. Haleem and Abdel-Aty (2010) examined crash injury severity for all crash types at unsignalized intersections in Florida using ordered probit, binary probit, and nested logit models. One finding from this study of particular relevance is that young at-fault drivers were less likely to experience severe injuries. Abdel-Aty (2003) developed separate ordered probit models to examine driver injury severity of crashes occurring at signalized intersections, toll plazas, and road segments. Exclusive to the signalized intersection model, it was found that at-fault drivers were less likely to sustain injuries than not at-fault drivers. Helai et al. (2008) developed a Bayesian hierarchical binomial logistic model to examine driver injury severity at intersections and found that at-fault drivers were more likely to be severely injured. In general, prior research has not explicitly examined the differences in injury outcomes between the at-fault and not-at-fault parties.

To address this gap in the research literature, a random parameters bivariate ordered probit (RPBOP) model is estimated to analyze factors affecting the injury severity of each crash-involved driver. In the transportation research literature, bivariate ordered probit (BOP) models have been utilized to examine outcomes or decisions that may be correlated. As one example, Anastasopoulos et al. (2012a) estimated a BOP model to examine automobile and motorcycle ownership. However, research utilizing BOP models in the context of traffic safety is limited. Mannering and Bhat (2014) provide a summary of recent methodological approaches that have been used to analyze both crash frequency and crash injury severity, noting several examples of bivariate/multivariate ordered probit models. Yamamoto and Shankar (2004) used a BOP model to simultaneously examine the injury level of the driver and most severely injured passenger in single-vehicle collisions with fixed objects. de Lapparent (2008) used BOP models to jointly analyze seat belt use and crash-related injury severity. Chiou et al. (2013) used a bivariate generalized ordered probit (BGOP) model to examine driver injury severity in two-vehicle crashes. Various other statistical techniques have been used to account for potential correlation or endogeneity in injury severity outcomes. Examples include a copula-based approach to simultaneously examine the degree of injury sustained by drivers, front seat passengers, and rear-seat passengers (Eluru et al., 2010); a copula-based joint multinomial logit-ordered