Analytic Methods in Accident Research 7 (2015) 1–15

Contents lists available at ScienceDirect

Analytic Methods in Accident Research

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

Analyzing the continuum of fatal crashes: A generalized ordered approach

Shamsunnahar Yasmin [a,1], Naveen Eluru [b,*], Abdul R. Pinjari [c,2]

[a] *Department of Civil Engineering & Applied Mechanics, McGill University, Suite 483, 817 Sherbrooke St. W., Montréal, Québec, Canada H3A 2K6*

[b] *Department of Civil, Environmental and Construction Engineering, University of Central Florida, Suite 301D, 4000 Central Florida Blvd., Orlando, FL 32816, USA*

[c] *Department of Civil and Environmental Engineering, University of South Florida, USA*

ARTICLE INFO

Article history:
Received 18 August 2014
Received in revised form
29 March 2015
Accepted 30 March 2015
Available online 16 May 2015

Keywords:
Generalized ordered logit
Endogeneity
Two-stage residual inclusion
FARS
Elasticities

ABSTRACT

In the United States, safety researchers have focused on examining fatal crashes (involving at least one fatally injured vehicle occupant) by using Fatality Analysis Reporting System (FARS) dataset. FARS database compiles crashes if at least one person involved in the crash dies within 30 consecutive days from the time of crash along with the exact timeline of the fatal occurrence. Previous studies using FARS dataset offer many useful insights on what factors affect crash related fatality, particularly in the context of fatal vs. non-fatal injury categorization. However, there is one aspect of fatal crashes that has received scarce attention in the traditional safety analysis. The studies that dichotomize crashes into fatal vs. non-fatal groups assume that all fatal crashes in the FARS dataset are similar. Keeping all else same, a fatal crash that results in an immediate fatality is clearly much more severe than another crash that leads to fatality after several days. Our study contributes to continuing research on fatal crashes. Specifically, rather than homogenizing all fatal crashes as the same, our study analyzes the fatal injury from a new perspective by examining fatality as a continuous spectrum based on survival time ranging from dying within 30 days of crash to dying instantly (as reported in the FARS data). The fatality continuum is represented as a discrete ordered dependent variable and analyzed using the mixed generalized ordered logit (MGOL) model. By doing so, we expect to provide a more accurate estimation of critical crash attributes that contribute to death. In modeling the discretized fatality timeline, the Emergency Medical Service (EMS) response time variable is an important determinant. However, it is possible that the EMS response time and fatality timeline are influenced by the same set of observed and unobserved factors, generating endogeneity in the outcome variable of interest. Hence, we propose to estimate a two equation model that comprises of a regression equation for EMS response time and MGOL for fatality continuum with residuals from the EMS model to correct for endogeneity bias on the effect of exogenous factors on the timeline of death. Such research attempts are useful in determining what factors affect the time between crash occurrence and time of death so that safety measures can be implemented to prolong survival. The model estimates are augmented by conducting elasticity analysis to highlight the important factors affecting time-to-death process.

* Corresponding author. Tel.: +1 407 823 2841; fax: +1 407 823 3315.
E-mail addresses: shamsunnahar.yasmin@mail.mcgill.ca (S. Yasmin), naveen.eluru@ucf.edu (N. Eluru), apinjari@eng.usf.edu (A.R. Pinjari).
[1] Tel.: +1 514 398 6823; fax: +1 514 398 7361.
[2] Tel.: +1 813 974 9671; fax: +1 813 974 2957.

http://dx.doi.org/10.1016/j.amar.2015.03.001
2213-6657/

1. Introduction

Road traffic crashes and their consequences such as injuries and fatalities are acknowledged to be a serious global health concern. In the United States (US), motor vehicle crashes are responsible for more than 90 deaths per day (NHTSA, 2012). Moreover, these crashes cost the society $230.6 billion annually (GHSA, 2009). In an attempt to reduce the consequence of road traffic crashes and to devise countermeasures, transportation safety researchers study the influence of various exogenous variables on vehicle occupant injury severity. In identifying the critical factors contributing to crash injury severity, safety researchers have focused on either examining fatal crashes (involving at least one fatally injured vehicle occupant) or traffic crashes that compile injury severity spectrum at an individual level (such as no injury, possible injury, non-incapacitating injury, incapacitating injury and fatality). In the US, the former category of studies predominantly use the Fatality Analysis Reporting System (FARS) database (see Zador et al., 2000; Gates et al., 2013) while the latter group of studies typically employ the General Estimates System (GES) database (see Kockelman and Kweon, 2002; Eluru and Bhat, 2007; Yasmin and Eluru, 2013). FARS database compiles crashes if at least one person involved in the crash dies within 30 consecutive days from the time of crash. Further, FARS database reports the exact timeline of the fatal occurrence within 30 days from the time to crash.

A number of research efforts have examined the impact of exogenous characteristics (such as driver characteristics, vehicle characteristics, roadway design and operational attributes, environmental factors and crash characteristics) associated with fatal crashes employing crash data with at least one fatality. These studies employed two broad dependent variable categorizations – (1) fatal/non-fatal or (2) fatal/serious injury. The binary categorization was analyzed employing descriptive analysis or logistic regression methods for identifying the critical factors affecting fatal crashes (for example see Zhang et al., 2013; Al-Ghamdi, 2002; Huang et al., 2008; Travis et al., 2012). Several studies have also investigated the factors affecting the involvement in a fatal crash as a function of individual characteristics. The important individual behavioral determinants of fatal crashes include excessive speed, violation of traffic rules and lack of seat belt use (Siskind et al., 2011; Valent et al., 2002; Sivak et al., 2010; Viano and Parenteau, 2010). Other driver attributes such as aggressive driving behavior, unlicensed driving and distraction during driving are identified to be the most significant contributors of fatal crashes for young drivers (Lambert-Bélanger et al., 2012; Hanna et al., 2012; Chen et al., 2000). Studies have also examined the effect of race/ethnicity in fatal crashes (Braver, 2003; Romano et al., 2006; Campos-Outcalt et al., 2003; Harper et al., 2000). On the other hand, most critical factors identified from earlier research for older drivers in fatal crashes are frailty and reduced driving ability (Baker et al., 2003; Lyman et al., 2002, Thompson et al., 2013). Gates et al. (2013) investigate the influence of stimulants (such as amphetamine, methamphetamine and cocaine) on unsafe driving actions in fatal crashes. Stübig et al. (2012) investigate the effect of alcohol consumption on preclinical mortality of traffic crash victims (see also Fabbri et al., 2002).

Many of the earlier studies also focused on the vehicular characteristics of fatal crashes (Fredette et al., 2008) and demonstrated that the relative risk of fatality is much higher for the driver of lighter vehicle (sedan, compact car) compared to those in the heavier vehicle (SUV, Vans, and Pickups). Among the environmental factors, it was found that collision during night time (Arditi et al., 2007) has the most significant negative impact on fatality risk in a crash. In terms of crash characteristics, head-on crash and crashes on high speed limit road locations increased the probability of fatalities in a crash (Fredette et al., 2008; Bédard et al., 2002).

These studies offer many useful insights on what factors affect crash related fatality, particularly in the context of fatal vs. non-fatal injury categorization. However, there is one aspect of fatal crashes that has received scarce attention in the traditional safety analysis. The studies that dichotomize crashes into fatal vs. non-fatal groups assume that all fatal crashes in the FARS dataset are similar. Keeping all else same, a fatal crash that results in an immediate fatality is clearly much more severe than another crash that leads to fatality after several days. In fact, there is evidence from epidemiological studies (Tohira et al., 2012) that the risk factors associated with early trauma deaths of crash victims are different from the risk factors associated with late trauma deaths. For instance, Tohira et al. (2012) reported that older drivers (aged 65 years or older) and/or crash victims with a depressed level of consciousness were at increased risk of late trauma death. Research attempts to discern such differences are useful in determining what factors affect the time between crash occurrence and time of death so that countermeasures can be implemented to improve safety situation and to reduce road crash related fatalities. Early Emergency Medical Service (EMS) response is also argued to potentially improve survival probability of motor vehicle crash victims (Clark and Cushing, 2002; Clark et al., 2013). In fact, Meng and Weng (2013) reported 4.08% decrease in the risk of death from one minute decrease in EMS response time, while Sánchez-Mangas et al. (2010) reported that a ten minutes EMS response time reduction could decrease the probability of death by one third. Given the import of this variable, it is also important to explore the effect of EMS response time in examining crash fatalities.

The objective of our study is to identify the associated risk factors of driver fatalities while recognizing that fatality is not a single state but rather is made up of a timeline between dying instantly to dying within 30 days of crash (as reported in the FARS data). The detailed information available in FARS provides us a continuous timeline of the fatal occurrences from the time of crash to death. This allows for an analysis of the survival time of victims before their death. To be sure, earlier research efforts also focused on examining the factors influencing the time period between road crash and death (Golias and Tzivelou, 1992; Marson and Thomson, 2001; Feero et al., 1995; Al-Ghamdi, 1999; Gonzalez et al., 2006, 2009; Brown et al. 2000). These studies demonstrated that nature of injury, EMS response time and pre-hospital trauma care were the main factors affecting the time till death and concluded that timely EMS response with proper pre-hospital trauma care may improve the survival outcome. For analysis of the time to death data, these studies employed univariate statistical analysis