Analytic Methods in Accident Research 8 (2015) 7–32

Contents lists available at ScienceDirect

Analytic Methods in Accident Research

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

The temporal stability of factors affecting driver-injury severities in single-vehicle crashes: Some empirical evidence

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ARTICLE INFO

Article history:
Received 15 April 2015
Received in revised form
5 July 2015
Accepted 26 August 2015
Available online 26 September 2015

Keywords:
Single-vehicle crashes
Driver-injury severity
Temporal stability
Transferability
Mixed logit
Marginal effects

ABSTRACT

This study explores the temporal stability of factors affecting driver-injury severities in single-vehicle crashes. Using data for single-vehicle crashes in Chicago, Illinois from a nine-year period from January 1, 2004 to December 31, 2012, separate annual models of driver-injury severities (with possible outcomes of severe injury, minor injury, and no injury) were estimated using a mixed logit model to capture potential unobserved heterogeneity. Likelihood ratio tests were conducted to examine the overall stability of model estimates across time periods and marginal effects of each explanatory variable were also considered to investigate the temporal stability of the effect of individual parameter estimates on injury-severity probabilities. A wide range of variables potentially affecting injury severities was considered including driver-contributing factors, location and time of day, crash-specific factors, driver attributes, roadway characteristics, environmental conditions, and vehicle characteristics. The results indicated that, although data from different years share some common features, the model specifications and estimated parameters are not temporally stable. In addition, complex temporal stability behaviors were observed for individual parameter estimates such as driver gender, apparent physical condition of driver, type of vehicle, vehicle occupancy, road surface, weather, and light conditions. It is speculated that this temporal instability could be a function of the urban nature of the data, possible variations in police-reporting of crash determinants over time, the impact of continuing improvements in vehicle safety features and drivers' response to them, and/or the effects of macroeconomic instability that was present over the time period considered in this study. Although the source of temporal stability is not clearly known, the general subject of temporal instability warrants substantial attention in future research. The possible presence of temporal instability in injury-severity models can have significant consequences in highway-safety practice where accurate forecasting of the impacts of alternative safety countermeasures is sought.

1. Introduction

Highway crashes are one of the main causes of death in the U.S., and they impose a tremendous economic and emotional burden on society. They are also the leading cause of death in the U.S. among individuals 5–24 years of age (Murphy et al.,

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http://dx.doi.org/10.1016/j.amar.2015.08.001
2213-6657/

2012). As a result, numerous studies have been conducted in an effort to identify the risk factors associated with the occurrence and severity of highway crashes. The findings from these studies have undoubtedly helped to reduce the number of crashes as well as the injury severity of those involved in the crashes by encouraging the implementation of appropriate improvements in vehicle and roadway design.

However, one element that has not been adequately studied in the past is the temporal stability of the factors that affect the frequency and severity of crashes. Temporal stability is particularly important in assessing the impact of safety countermeasures because, if the influence of the factors is temporally unstable, it is impossible to determine how much of the change in the frequency and severity of crashes is due to the implementation of specific safety countermeasures, and how much is attributable to changes in the effect of specific factors over time.

Past work has uncovered evidence which suggests that temporal stability may be a major concern in crash modeling, which may have substantial implications for the future editions of the Highway Safety Manual (Venkataraman et al., 2014). For example, Malyshkina et al. (2009) estimated a Markov switching model of crash frequency which indicated that the frequency of crashes fundamentally shifted between states, over time, due to unobserved factors. Subsequent work has also shown that the severity of crashes is not stable overtime (Malyshkina and Mannering, 2009; Xiong et al., 2014), with unobserved heterogeneity again suggesting Markov transitioning between multiple states. While the empirical findings from these studies suggest time-varying heterogeneity over relatively short time periods,[1] they do not explicitly address the issue of possible long-term shifts in the effect that specific explanatory variables may have on the frequency and/or severity of crashes. In fact, one can imagine long-term shifts in the effect of explanatory variables to result from changes from a variety of factors including drivers' behavioral adaptation to changes in vehicle safety technologies[2] and roadway-safety features, the effects that macroeconomics, and so on. The potential importance of macroeconomic effects is particularly noteworthy. For example, it has been well documented that adverse macroeconomic conditions result in a decline in the number of motor-vehicle fatalities per distance driven (Ruhm, 2000), with the percentage decline in fatalities far exceeding the percentage decline in distance traveled that one would expect in an economic downturn (Peterman, 2013). Recent disaggregate work by Maheshri and Winston (2015) has provided evidence that at least some of the reduction in fatality rates observed during economic downturns is due to a change in the mix of travel, with the share of mileage driven by riskier drivers declining relative to their safer driver counterparts.

Another potential source of temporal instability relates to data collection. Most safety studies rely on police-reported data and, although officers are strictly trained for consistency in their reporting, potential changes in police-reporting practices over time (such as opinions relating to the primary cause of the crash, the apparent condition of the driver, etc.) could give the appearance of temporal instability with regard to crash determinants.

This paper will address possible temporal instability, potentially resulting from a variety of sources, by focusing on modeling driver-injury severity. In so doing, our analysis will be conditional on a crash having occurred, so the issue of accumulated distance driven does not enter as a factor. This will allow us to focus on how the fundamental effect of explanatory variables may change over time.

Using multiyear data from the city of Chicago, the objective of this study will be to estimate diver-injury severity models for each calendar year, and to test whether the resulting parameter estimates for the explanatory variables are stable over time. The analysis will also consider changes in the marginal effects of explanatory variables over time, to investigate potential temporal changes in the effect of individual parameter estimates on injury-severity probabilities. As will be shown, the findings of this paper will provide some new insights into the degree of temporal stability in models of crash-injury severity.

2. Methodology

In the forthcoming empirical analysis, driver-injury severities, in single-vehicle crashes, are studied by considering three discrete driver-injury severity levels: severe injury (fatal or incapacitating), minor injury (non-incapacitating or possible injury), and no injury (property damage only). Over the years, crash-injury severities such as these have been modeled using a wide variety ordered and unordered discrete outcome methodological approaches such as ordered logit/probit models, multinomial logit models, dual-state multinomial logit models, nested logit models, latent class models, mixed logit models, Markov-switching models, and others (see Savolainen et al., 2011). Currently, almost all front-line crash-severity research applies what can be broadly termed as "heterogeneity models", which are a class of models that explicitly consider the potential unobserved heterogeneity that exists in crash-severity data (Mannering and Bhat, 2014). Such models, through a variety of alternate approaches, allow the effects of explanatory variables on crash-injury severities to vary across the observations or groups of observations to account for unobserved heterogeneity in the data (Mannering and Bhat, 2014). Among these heterogeneity models, random parameters models (such as the mixed logit model) and latent class models, or

[1] Interestingly, Pahukula et al. (2015) estimated separate injury-severity models for different time periods in a day. They found that the effects of explanatory variables were different from one time of day to another. This shows the importance of potential temporal effects by time of day.

[2] For example, Winston et al. (2006) found that drivers responded to the introduction of vehicle safety features such as airbags and antilock brakes, by driving more aggressively, thus seriously compromising the safety benefits of these devices. The results of this study suggest the presence of risk-compensating behavior that could manifest itself in a temporal instability of model parameters.