Accident Severity and Young and Old Drivers:

Evidence from Saskatchewan 1991-2012

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Major Paper presented to the

Department of Economics of the University of Ottawa

in partial fulfillment of the requirements of the M.A. Degree

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Ottawa, Ontario

December 2014

Abstract

This paper investigates the effects of several driving factors on the severity of accidents in the Province of Saskatchewan, Canada. The data provided by the Saskatchewan Government Insurance (SGI) contains detailed accident information related to driving behaviours, risky factors, vehicle and environmental features and allows me to analyse their impact on the injury severity of accidents. I find that different driving behaviours when comparing the performance of young and old drivers and the whole population. I find the young and old drivers are more dangerous compared to middle-age drivers, but the youngest female drivers are more vulnerable to suffering severe accidents, while the oldest female drivers are not. In addition, marginal effect analysis illustrates that the possibilities of experiencing more severe accidents increases with drivers' age, and decreases with the number of occupants in a vehicle for both young and old drivers. These results also suggest some potential policy uses.

Key words: Severity of Accident; Driving Behaviour; Young and Old Drivers; Saskatchewan

Content

1. Introduction

Motor vehicle fatalities and injuries have long been a global public health concern. Although Canada has experienced a sustained downward trend for vehicle-related deaths and injuries rates since 1979, motor vehicle crashes remain the leading cause of fatal and non-fatal injury among children, teens and young adults, and the fifth cause of fatal injuries among seniors in recent years (Public Health Agency of Canada 2012; Statistics Canada 2012).

In addition, young and old drivers are continually overrepresented as victims on the road. Only 12 percent of all licensed drivers are young drivers between the ages of 16 to 24, but they contributed to 22 percent of road fatalities and 24 percent of injuries in 2012. Correspondingly, 14 percent are old licensed drivers who account for 19 percent of road deaths and 12 percent of road injuries. In the meantime, middle-aged drivers experienced relatively low rates.(Transport Canada 2013). Old drivers have relatively lower risk of injuries typically because they are more experienced than young and middle-aged drivers. However, their driving abilities tend to be compromised by an age-related reduction in "cognitive and physical fitness", such as vision reduction and increased reaction time (Transport Canada 2011).

Other types of road users were also affected by vehicle accidents which cause enormous economic burdens. According to the Traffic Injury Research Foundation (TIRF), the aggregate economic costs associated with vehicle accidents were estimated to be $25 billion in 2009, when taking account of direct and indirect costs as well as the costs of pain and suffering.

There is a rich literature on the impact of a host of different risk driving factors on the accident rates, and to a lesser extent on the severity of accidents. Driver characteristics, such as age and gender, are typically the most basic determinants (e.g. Glendon et al. 1996; Rhodes and Pivik 2011). Other risk factors, such as drinking and driving, speeding and night driving have also been recognized (e.g. Jewell and Brown 1995; McCarthy 2003; Weiss, Kaplan and Prato 2014). Researchers also have studied a bunch of related policies, such as the impacts of legal alcohol accessibility (Kreft and Epling 2007; Carpenter and Dobkin 2009; Lindo, Siminski and Yerokhin 2014), safety equipment restraint (Carpenter and Stehr 2008; Dissanayake and Ratnayake 2008), graduated driver's license policies (Williams and Mayhew 2004; Carpenter 2006; Morrisey and Grabowski 2011; Ehsani, Bingham and Shope 2013), liability insurance rules (Devlin 1992; Devlin 1999; Cummins, Phillips and Weiss 2001; Cohen and Dehejia 2004), speed limit adjustments (Kweon and Kockelman 2010), to name but a few. The safety equipment restraint policy is always associated with endogenous seat belt use and driving behaviour compensations (Peltzman 1975; Cohen and Einav 2003; Abay, Paleti and Bhat 2013). It is clear that drivers could behave differently in response to different policy incentives.

Most research on driving behaviour focuses on the driving population as a whole (McCornac 1993; Ehsani, Bingham and Shope 2013). Often, these papers are looking at aggregate driving outcomes: property damage only accidents, non-fatal accidents and total fatal accidents (Garcia-ferrer, De Juan and Poncela 2007; Kreft and Epling 2007;

Anderson 2008), or fatalities per mile or per population (Jewell and Brown 1995; Lindo, Siminski and Yerokhin 2014). Some research uses micro-data and looks at similar influences (e.g. Levitt and Porter 2001; Dissanayake and Ratnayake 2008), but a few are able to exploit cross-sectional data in order to look more closely at an individual driving behaviour(Kweon and Kockelman 2010), injury levels (Dissanayake and Ratnayake 2006) and its dynamics over the years (Perera and Dissanayake 2010; Abay, Paleti and Bhat 2013; Weiss, Kaplan and Prato 2014). This paper is able contribute to this small group of papers because of the nature of the dataset that is employed.

The purpose of this paper is to conduct an empirical analysis of the severity of traffic accidents, focusing on young drivers (aged 16 - 24) and older ones (aged 65 and over). This paper makes three contributions. First, it adds to the very few papers that focus on the driving behaviour of these two key groups: the young and old drivers. These groups are chosen as they are generally considered to be the "riskier" drivers on the road. It used to be that it was the young drivers who were the most likely to get into an accident. However, with the changing demographics and the increasing proportion of the older drivers on the road, we are seeing a change in the riskiness of that older population as well. Second, this paper exploits a unique data set from the province of Saskatchewan, Canada, on motor vehicle accidents; it is the first to use this dataset to explore the behaviour of young and old drivers. Moreover, the data set allows me to include a number of factors that are usually not available, like the time of the day (night versus day, rush hour versus otherwise), months of the accident, and road conditions. Finally, the paper is one of very few that examines the impact of having passengers in the car on the severity of the injuries sustained.

The paper is structured as follows. Section 2 discusses the literature regarding the major factors contributing to vehicle accidents. Section 3 describes and summarizes the dataset and provides simple statistical descriptions. Section 4 derives the econometric model. Section 5 discusses the empirical results from the analysis. Finally, section 6 provides some conclusions with regard to possible economic and policy uses.

2. Literature Review

Young and old drivers are overrepresented in road accidents. Quite a few studies have evaluated the determinants of vehicle accidents among young drivers (e.g. Carpenter 2006; Morrisey and Grabowski 2011; Weiss, Kaplan and Prato 2014) and old drivers (e.g. Loughran, Seabury and Zakaras 2007; Perera and Dissanayake 2010) separately. Many factors that can impact the relationship between vehicle collision and the severity of injury have been identified, and generally, can be grouped into four categories: personal characteristics, age and gender; risk driving factors, drinking and driving, the number of occupants, the use of seatbelts, driving distractions; traffic safety policies, minimum legal drinking age, speed limits, driver license classification, insurance liability; and driving environments, road conditions, weather, driving time.

2.1. Personal characteristics

Young drivers are typically thought to be more dangerous and vulnerable among all age groups due to a lack of driving experience (Glendon et al. 1996; Rhodes and Pivik

2011). However, elderly drivers are also being recognized as having age-related cognitive and physical reaction problems in completing specific driving tasks, which is the main reason that old drivers are the most dangerous at, for instance, intersections (Transport Canada 2013). When comparing experienced young and old drivers, Brouwer et al. (1991) suggest that old drivers have a relative lack of "ability to divide attention" on optical and vocal signals than experienced young drivers, by using data gathered from their dynamic simulated driving experiments. They also argue that older drivers are more dangerous due to their slower physical responses on completing driving tasks. Wood and Mallon (2001) find the evidence that the presence of older drivers with vision problems is highly correlated with traffic accidents.

Male drivers are typically found to engage in more risky driving behaviours and more aggressive driving than female ones by age group (Rhodes and Pivik 2011). One reason why this is the case is underscored by Glendon et al. (1996) who find that males drive longer and more frequently. They also find that young male and female drivers have similar safety driving behaviour and judgment performance, while old male drivers have slightly better driving behaviour performance, but much worse judgment performance on responding to risk signals compared to young male drivers (Kweon and Kockelman 2010; Weiss, Kaplan and Prato 2014).

2.2. Risk Factors

One of the most dangerous risk factors is drinking and driving. According to Saskatchewan Government Insurance (2014), 39 percent of fatal collisions and 8 percent of injury collisions involve alcohol. There is no doubt that the probability of vehicle accidents increases significantly when driving under the influence. Drunk drivers tend to be overconfident and overestimate their driving abilities and their ability to handle liquor (Simons-Morton, Lerner and Singer 2005). Levitt and Porter (2001) demonstrate that drivers who have been drinking are at least seven times more likely to cause fatal crashes than sober drivers in the US, when looking at accident occurences.

Only few scholars have been able to directly study the impact of the number of occupants in the vehicle on accidents and their severity. Doherty, Andrey and MacGregor (1998) suggest that younger drivers accompanied by young passengers are much more likely to be involved in an accident than any other types of road users, especially when they drive at nighttime. Notably, it is only drivers aged 16 to 19 that are more prone to accidents when passengers are in the car. Simons-Morton, Lerner and Singer (2005) investigate the impact of the presence of passengers in a young drivers' vehicle and related accidents and find that teenage drivers drove faster than the general traffic, especially in the presence of a male teenage passenger, and concluded that the presence of male teenage passengers was associated with risky driving behaviour among teenage drivers. Williams, Ferguson and McCartt (2007) conclude that the presence of passenger, especially male passengers, raise the accident risk for teenage drivers due to passenger-related distraction and driving inexperience, while female passengers do not have the same effect. They also suggest that policy restrictions on driving, such as graduate driver licensing policies and parental monitoring, have been effective in reducing accident problems. Weiss, Kaplan and Prato (2014) find that severe injuries of young drivers are highly associated with the presence of passengers in both single-vehicle and two-vehicle crashes, by analyzing the effects of young drivers' characteristics in New Zealand between 2002 and 2011.

The use of seat belts can significantly reduce the severity of injuries arising from accidents. Dissanayake and Ratnayake (2010) show this by using highway crash data in Kansas; Kweon and Kockelman (2010) do by using 2000 national data of Motor Vehicle Occupant Safety Survey (MVOSS) in the US. However, it has been shown that seat belt use is also associated with changes in driving behaviour known as the "Peltzman effect" (Peltzman 1975). This change means that "people offset the restraint benefits of seat belts use by driving more aggressively" (Abay, Paleti and Bhat 2013, 76) and road danger increases(offsetting behavior hypothesis) (Cohen and Einav 2003; Abay, Paleti and Bhat 2013), or dangerous drivers become safer after belt-restrained and road accidents decrease (selective recruitment hypothesis) (Abay, Paleti and Bhat 2013).

There are many papers that show that vehicle characteristics can affect vehicle accidents, such as: vehicle model, vehicle mass and vehicle types (White 2004; Loeb and Clarke 2007; Anderson 2008). The increase in vehicle mass can improve traffic safety for own drivers, but the net benefit could be alleviated when considering the extra injuries to other road users (Anderson 2008). Similar conclusions are also found with car types (White 2004), that bigger vehicles (e.g. SUV and pickup trucks) are safer to own drivers but dangerous to others. Moreover, drivers of larger cars may change driving behaviours and become more aggressive drivers (Li 2009).

Several other risk factors are reported by SGI (2014), such as driving inattentions, driving distractions and failure to yield right-of-way. These factors tend to have intuitive implications of the severity of accidents, and will be discussed in the next part.

2.3. Traffic Safety Policies

The graduated driver licensing (GDL) policy became popular in Canada since it was first introduced in Ontario in 1994 and in all Canadian provinces by the end of 2015. The GDL program has undoubtable fundamental impacts on reducing young drivers' deaths, by allowing novice drivers to gain experience under supervisors and by imposing restrictions to avoid risky environment, such as: drinking and driving, night driving and driving with other young passengers (SGI 2014). However, few studies exist in Canada on this policy. Carpenter (2006) concludes that the GDL program in Ontario has no significant impact on alcohol-related traffic accidents, by using the dataset of Ontario Student Drug Use Surveys 1983-2001. To strengthen the understanding of how the program works, Chang, Wu and Ying (2012) study the quality of both the number of months and hours spent on training using data derived from the Fatalities Analysis Reporting System (FARS) from the years of 1990-2009. They conclude that besides the supervision of experienced drivers, an at-least six-month period is necessary to reduce the fatality rate in the US.

Alcohol control policies have long been a highly debated issue. One of the most studied policies is the minimum legal drinking age (MLDA) of 21 in all US states after 1984. Both Carpenter and Dobkin (2009) and Lindo, Siminski and Yerokhin (2014) apply an age-based regression discontinuity design to estimate the drinking behaviour changes before and after 21. To be specific, Carpenter and Dobkin (2009) discover an unusually significant increase in motor vehicle fatalities at age 21 due to the increased alcohol consumption of newly turned 21 years old young adults in the US, and they suggest that the age restriction on alcohol is effective in reducing drinking and driving fatalities. In addition, Lindo, Siminski and Yerokhin (2014) reach similar conclusions using a sample from New South Wales, Australia. They suggest that strong alcohol-related legislation and regulations could improve drinking and driving behaviours. Kreft and Epling (2007) suggested that the increased MLDA in Michigan could decrease teenager accident fatalities in the long term, but evidence also suggested that this was partly due to border crossings, since Ontario has lower MLDA.

Governments are also concerned about the usage of other intoxicating substances and possible substitution effects, the most recognized example being marijuana (Anderson, Hansen and Rees 2013). As early as 1994, Chaloupka and Laixuthai analyzed data from 1982 - 1989 of high-school seniors and their alcohol consumption and consumption of other kinds of drugs. They suggest that there may be reductions in accidents arising from substitution away from other intoxicating substances to marijuana, as the full price of the latter one is "lower more than offsets the increase in accidents related to marijuana use" (Chaloupka and Laixuthai 1994, 1).

Furthermore, the legal liability regime governing vehicle accidents may also affect drivers' behaviour. For example, no-fault liability insurance tends to increase accident injury rates and fatalities (Devlin 1997) due to increasing "moral hazard costs" (Cohen and Dehejia 2004). Devlin (1992) also studied the impacts of insurance rules switching from a liability regime to a no-fault one on vehicle accidents by using data on Quebec. The possibility that liability choice rules may affect behaviour was also studied using 1990-2011 data from Saskatchewan Government Insurance.

Driving speeds are highly correlated with the severity of vehicle accidents. Clearly, the actual driving speed choice can be influenced by a lot of factors (Kweon and Kockelman 2010). Chipman et al. (1992) study the impacts of traveling time and distance on the injury severity of accidents by using the sample of Ontario licensed-drivers. They illustrate that old drivers generally drive slowly, which led to less severe vehicle accidents. Haglund and Åberg (2000) find that one of the most influenced speed-related factors is the driver's relative speed to others by using the Swedish data with a 90 km/h highway speed limit. They also conclude that drivers tend to slightly overestimate other drivers' speed and largely overestimate the proportion of high-speed drivers. To this end, the increase of 4-lane highway speed limits in Saskatchewan since 2003 has general considerable impacts of the overall incidence of vehicle accidents and the injury severity level.

The mandatory use of seatbelts has also been the subject of much discussion (Dee 1998; Cohen and Einav 2003; Carpenter and Stehr 2008; Traynor 2009). The effects of safety equipment policies on accidents have revealed surprising results. In particular, Cohen and Einav (2003) examined a panel dataset from the US from 1983 to 1997, with findings that are consistent with the offsetting behaviour hypothesis, that the mandatory seat belt laws mildly decrease accident fatalities. However, Carpenter and Stehr (2008) combine several datasets from the years 1991 to 2005, studying state seatbelt law amendments and find that a 50 percent increase in seatbelt use among high school age youths caused by the state mandatory seatbelt laws, and a resulting reduction of more than eight percent of traffic fatalities and serious injuries. It has also been found that the impact of seat belt use differs across age groups (Williams and Shabanova 2002).

2.4. Driving environments

Doherty, Andrey and MacGregor (1998) investigate the effect of temporal factors on accidents, namely the time of day and the day of the week, by combining two datasets derived from the Ontario Ministry of Transportation. They demonstrate that more accidents happen on weekends among all age groups, while drivers with passengers have slightly higher risks.

Factors, like the month of year, help to pick up seasonal effects. Ramage-Morin (2008) has described the statistical fact that warmer months (summer, and if possible, relatively warmer winter months) experience more motor vehicle accidents and increasing injury levels, compared to colder months, based on data on vehicle accidents in Canada spanning 1979-2004.

Other aggregate factors have been shown to affect accidents, such as economic growth (Kopits and Cropper 2005) and income levels and inequality (Anbarci, Escaleras and Register 2009). These factors will not be emphasized here because of data limitations.

3. Data

The primary data source on motor vehicle accidents used in this paper is the Traffic Accident Information System (TAIS) database of the Saskatchewan Government Insurance (SGI) agency, which is the compulsory automobile insurer in Saskatchewan. This database collects information on all vehicle accidents reported through the SGI's claims process, and hence represents an ideal database for studying driving behaviour in Saskatchewan. The initial database contains 612,387 observations from 1988 to 2012, providing detailed information about the characteristics of drivers, occupants and accidents. It includes one record for each individual involved in the vehicle accidents occurring on Saskatchewan roads. Since the factors influencing the severity of injuries sustained by occupants and pedestrians are different from those of drivers – especially behavioural factors (like speed and distracted driving), I focus on the data of the injuries of drivers only in this paper. I thus extract data on the drivers of cars, pickup trucks, or vans less than 4,500 kilograms gross weight who were involved in accidents over this period (1988 to 2012). For the same reason, I also exclude the few drivers who were under the minimum legal driving age of 16 or had missing or incomplete data about age. Thus, the final dataset used in this paper contains 136,731 records, spanning the years of 1991-2012[1], with 37 percent of the whole group being young drivers from 16 to 25 years old (50,285 observations) and nine percent being older drivers of 65 years and more (11,614 observations).

[1] The dataset available is from1988 to 2012, but no level 4(major unconsciousness) injuries were record in 1988-1990, so I drop out those years.

The variables used in this analysis are based on the availability of data in the TAIS database and the literatures discussed. Many of the variables included in the empirical model follow the work of Devlin, Ghazal and Barham (2012). In order to examine the factors influencing the severity of accidents, more than 20 basic factors and some derived variables are included as independent variables. Table 1 defines all of the variables used in the regression analysis.

The severity of motor vehicle accident injuries is the dependent variable. The TAIS database records the severity of injuries in six levels: *no injuries* (only property damages, no obvious physical damages), *minor injuries* (visible damages and pains), *moderate non-incapacitating injuries* (apparent body damages which can be seen from the scene of accidents but not incapacitating), *major incapacitating injuries* (injuries that make victims incapable of walking, driving, or other activities which the victims undertook before the injury), and *major unconscious injuries* (the victim are unconscious at, or when taken from, the scene of accidents) and *fatal injuries* (within 30 days) (SGI 2014).

Figure 1 describes the number of collisions by victim's injury severity of accidents each year for the final dataset we used in this paper. Generally speaking, the aggregate injury level has experienced a gradual downward trend since 1990. Before 2008, the most general and least severe injury levels, *no injuries* and *minor injuries*, remain roughly at the same level, accounting for the largest proportions of all injury levels. Although the level of *minor injury* stays in a relatively stable range all these years, it fluctuates more than that of *no injury*. *Moderate* and *incapacitating injuries* decrease progressively, while *fatal injuries* remain steady at approximately 100 per year, with a peak of 133 in

1999. One should notice here the sharp decline of accidents involving no injuries in 2010, this was a direct consequence of a policy change that altered the dollar threshold below which property-damage only accidents were to be reported: from $1,000 to $5,000.[2]

Statistical evidence shows that male drivers at their young age also tend to be involved in speeding, aggressive driving and driving under the influence (DUI), leading to higher accident risks (SIRC 2004). Thus, several dummy age groups are included in my analysis in order to track the effects of age on injury severity.

The exact time of the accident, as well as its date and location, is available in the data set. Given that these are factors that have been shown to matter, they are also included in the regression. Drivers may be more likely to exceed speed limits when driving on highways at night or very early in the morning. Dummy variables for the month of the accident, as well as a year trend variable (and its square) are included. Furthermore, I calculate a variable to pick up whether the accident occurred at *night* (10pm to 4am[3]) or during *rush hour* (3pm to 6pm) to see how these factors might influence accident severity. I also note if the accident occurred on a major highway, as speed is always associated with more severe accidents.

The relationship between safety restraints, such as seat belts and air bags, and the prevention of traffic accidents is disputable. Statistical evidence shows that "vehicle occupants who did not fasten their seatbelts were 10 times more likely to be killed than those who wore ones." in Saskatchewan 2012 (SGI 2014, v). About 20 percent of

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2 "Effective Jan.1, 2010, the damage threshold for recording property damage only collisions from SGI's claims system into TAIS was increased from $1,000 to $5,000."(SGI 2010)

3 Other thresholds, e.g., 12a.m. to 4.a.m, do not alter the value of coefficients.

accidents in my dataset involved drivers with improperly worn safety equipment. Based on the dataset, I thus generate 2 dummy variables; one is *seatbelt* (drivers who wear seatbelts properly while driving), and the other is *airbag* (drivers who wear seat belts and were in a vehicle with air bags). Even considering the possible endogeneity of safety restraints (the Peltzman effect), one would expect such equipment to mitigate the severity of injuries – even though the wearing of such equipment may lead to riskier other behaviours[4].

The dataset records two measurements of weather conditions and another two for road conditions. The first is the actual weather conditions, such as *clear*, cloudy, *raining*, snowing and winds. The second one is a category based on whether the weather conditions are stated as a major contributing factor (*MCF*) of accidents or a disturbance of driving behaviour. Since one of the purposes of this paper is identifying the factors contributing to the severity of injuries from accidents, only actual weather conditions are included in the regression analysis.

Independent variables are grouped into the same four categories as in the literature review: drivers' characteristics, risky factors, policies and environments. In order to better understand the demographic characteristics of the sample, Table 2 provides descriptions about these variables for three samples: all drivers who are involved in accidents (n =136,731); young drivers aged 16-24[5] (n = 50,285); and those older drivers

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[4] The "selective recruitment hypothesis" is people offset the restraint benefits of seat belts use by driving more aggressively, and hence they remain dangerous or even at more risk.
[5] These kind of age group classifications are consistent with most research and the statistical report of SGI (2014).

aged 65 and over (n = 11,614).[6] In the following analysis, the whole sample with all licensed drivers will be the baseline, and I will compare the different performance between young and old drivers and the whole sample, in order to see the over- or under-representation on key factors.

In my dataset, male drivers are involved in more accidents than female drivers; this is especially true in the older driver sample (67 percent against 33 percent). Young drivers tended to have more passengers when they had accidents, while old driver did not. Across all three samples, drivers are more likely to be involved in double-vehicle accidents; the difference between single- and double-car accident occurrences of young people are small (three percent more), but quite large for old people (50 percent more).

Sixty percent of all accidents are minor accident in the full sample, which is the most among all injury categories, followed by moderate injuries (26 percent). Old drivers trend to suffer more severe accidents compared to young. Both young and old males have more fatal accidents than average, compared to females. Especially, old male drivers were reported to suffer more fatal accidents with three percent against 1.2 percent on average and 1.6 percent for the young driver sample.

Even though the mandatory use of seat belt laws has been legislated since 1977, there are still seven percent of men and three percent of women who did not wear seat belts properly, but this rate goes down with age: young drivers, 15 percent; old drivers, nine percent. One possible explanation is that this kind of drivers feels "they can beat

[6] Since the data in this paper varies from hours to years and almost all of them are binary, standard deviations, minimums and maximums do not have particular implications.

the odds"(Solof 2010).

Other risk factors are listed by SGI (2014). Old drivers are more likely to be involved in accidents caused by inattention and failure to yield, while young drivers not. On the contrary, driving after alcohol consumption is a much more popular problem among young drivers, while only a small proportion of older drivers engage in this sort of behaviour. In the summer, male drivers tend to have more accidents than females across all three samples. Interestingly, weather conditions do not seem to alter accidents too much; indeed a dominant proportion of accidents happened with good road conditions. Finally, driving at night seems to be a challenge for young drivers but not for others.

4. Model

The dependent variable can take on one of six values, representing no injuries to fatal injuries. It is thus a categorical variable, and the order of the categories makes sense – i.e., they go from no injury to the severest of injuries (death). Therefore, it is appropriate to use an empirical procedure that can deal with the categorical and ordered nature of the data. To this end, the ordered probit (OP) model is a good candidate for exploring the relationship between crash severity and influence factors.

The structural model for the ordered probit can be described as follows (Long and Freese 2006):

$$y_i^* = x_i\beta + \varepsilon_i \qquad (1)$$

where y_i^* represents the injury risk, a latent variable ranging from -∞ to ∞; and the measurement model can be expressed as,

$$y_i = m \quad \text{if } \tau_{m-1} \le y^* < \tau_m \quad \text{for } m = 1, \ldots, J \tag{2}$$

where y_i represents the severity level of injury, an ordinal discrete observation ranging from 1 to 6 in this paper. The observed variable y is categorized according to the threshold τ, which can be measured after estimating the coefficients of β. Clearly, J = 6, τ_0 = -∞ and τ_J = ∞. To be specific, y_i is described as follows,

$$y_i = \begin{cases} 1\ (\textit{not injured}) & \text{if } \tau_0 = -\infty \le y_i^* < \tau_1 = 0 \\ 2\ (\textit{minor}) & \text{if } \tau_1 \le y_i^* < \tau_2 \\ 3\ (\textit{moderate}) & \text{if } \tau_2 \le y_i^* < \tau_3 \\ 4\ (\textit{incapacitating}) & \text{if } \tau_3 \le y_i^* < \tau_4 \\ 5\ (\textit{unconscious}) & \text{if } \tau_4 \le y_i^* < \tau_5 \\ 6\ (\textit{fatal}) & \text{if } \tau_5 \le y_i^* < \tau_6 = \infty \end{cases} \tag{3}$$

According to (3), the probability that victim *i* is involved in an injury severity level of m is the probability that the injury propensity y_i^* takes a value between the threshold τ_{m-1} and τ_m. That is,

$$\Pr\ (y_i = m \mid x_i) = \Pr\ (\ \tau_{m-1} \le y_i^* < \tau_m \mid x_i) \tag{4}$$

The error term ε_i of the ordered probit model is assumed to be normally distributed with a mean of 0 and variance of 1. After substituting (1) into (4), the associated probability of suffering level m injury depends on the value between two respective thresholds, given a specific set of x, such as:

$$P_i = \begin{cases} \Pr(y_i = 1 \mid x_i) = \phi(\tau_1 - x_i\beta) \\ \Pr(y_i = m \mid x_i) = \phi(\tau_m - x_i\beta) - \phi(\tau_{m-1} - x_i\beta) \quad \text{if } 2 \le \text{m} < 6 \\ \Pr(y_i = 6 \mid x_i) = 1 - \phi(\tau_5 - x_i\beta) \end{cases} \tag{5}$$

where ϕ denotes the cumulative distribution function of the error term ε_i. So, based on a set of samples, the log-likelihood function is,

$$\ln L(\beta,\tau \mid y,X)=\sum_{j}^{n}\ln\left[P_i(y_i)\right]=\sum_{j}^{n}\ln\left[\phi(\tau_m - x_i\beta)-\phi(\tau_{m-1}-x_i\beta)\right] \qquad (6)$$

Since the probit model is highly non-linear, it is useful to report the marginal effects of the independent variables on the dependent variable, rather than the estimated coefficients per se. The marginal effects of changes in x_j on the probability of suffering level m injury, is evaluated as:

$$\frac{\partial \Pr(y_i = m \mid x_i)}{\partial x_{ij}}=\left[\phi\left(\tau_m - x_{ij}\beta\right)-\phi\left(\tau_{m-1}-x_{ij}\beta\right)\right]\beta_j \qquad (7)$$

The ordered probit model is an appropriate estimation method when the dependent variable is both categorical and ordered. As the final dataset includes 136,731 observations with the ages from 16 to 100, the ordered probit model is also preferred over other types of choice models. For instance, Ye and Lord (2014) emphasized that the OP model performed better in terms of goodness-of-fit and required a smaller sample size (at least 1,000) when compared to the mixed logit model and the multinomial logit model (Ye and Lord 2014). The normally distributed error term could be one limitation for regression.

5. Results

The ordered probit was estimated using the econometric package STATA 13. Since the parameter estimation in the ordered probit model assumes a linear relationship between the severity of the injury and independent variables, a positive value of a parameter indicates that the relevant variable increases the severity of the injury, while a negative value indicates the opposite. The bigger the value of the estimated parameter is, the larger its impact on the severity of the injury. I also present the estimated parameters in table form (tables 4) as well as in several figures (figures 2 to 4) that help to illustrate the marginal impact of two variables of particular interest to this paper – age and the presence of occupants in the car – on the predicted probability of an injury of a given type.

Columns (1) and (2) of table 4 present the estimation results for the full sample (drivers of all ages): the first column presents the estimation when age and age squared are included as regressors, whereas column (2) presents the specification when age is included as groups. Columns (3) and (4) present the estimated coefficients for the young sample (under 25 years of age), and the old driver sample (65 years and older). Several parameters share the same signs and significant levels across the four specifications. I now turn to a discussion of the influences on injury severity, organized by the four main categories of determinants previously described: personal characteristics; driving risk factors; traffic safety policies; and driving environments.

5.1. Personal characteristics

Looking first at the specification in column (1), one sees that the effect of age is not statistically significant, but its square is both positive and significant, similarly to Kockelman and Kweon (2002). In order to see what was going on with age, I estimated its effect using a series of dummy variables instead, with age 35-44 being the reference group. Here, my findings are consistent with some of the previous research (e.g. Turcotte 2012; Abay, Paleti and Bhat 2013) that the estimated coefficients of the younger groups are all negative, suggesting that the young have less severe accidents relative to the middle group; the estimated coefficients of the older groups, by contrast, is positive, suggesting that the older groups have more severe accidents.

The estimated coefficient on the female variable is positive, but in specifications with interactive terms, its significance is reduced. Interaction terms with gender and age groups are created to illustrate the combined effects of gender and age. Again, from column (2) I find that it is the youngest female age group (the interaction term of being female and aged of 16 to 20)that has a statistically significant and positive sign – indicating that they have more severe accidents relative to the representative group, a driver who is female and aged of 35 to 44 (female*age3544); senior female drivers aged 65 to 74 also have a positive coefficient and hence the same interpretation. The oldest female age group has a statistically significant and negative impact on severity. In addition, considering the interaction performance of drivers' age in both columns, females are more dangerous when calculating the effects of ages on injury levels compared to males. These findings are consistent with Al-Balbissi (2003) and SINC (2014).

Turning to column (3), one sees that for the young driving group, age (within that group) has a positive impact on severity, and its square is negative, suggesting a concave relationship. The older group (65 and older) displays the same pattern. Given that it is not statistically significant for the sample as a whole, my results suggest that the impact of age is much more pronounced for the tails of the age distribution rather than for the middle-aged group.

Another way to present the findings on age is to look at how age affects the predicted probability of having an injury of type i, *ceteris paribus*. Figure 2 presents six line graphs of the marginal effect of age by different injury levels (based on the results of the full sample). One can clearly see that, as drivers' age increase, only the marginal probability of having no injury or minor injury decreases (figures (a) and (b)), whereas all other more severe injuries clearly increase with age. The relationship between the age and probability of an injury of type minor (figure 2 (b)) has a concave shape that suggests the marginal effect of age is much larger for young drivers than otherwise. For example, a 16-years-old driver is very likely to get involved in a minor injury relative to someone a bit older. Indeed, when this driver becomes one year older, the possibility of suffering a level 2 injury decreases more quickly than that of other injury levels, holding other factor constants.

Finally, I note that the estimated coefficient of being female is positive for all three samples. At first glance, this result seems a bit counterintuitive, especially since the most literature is pretty clear that male drivers behave in a more risky manner. In order to better understanding what is going on, table 3 presents the number of accidents by each category by males and females. Across the board, males have more accidents. However, one can see clearly that males have proportionately more accidents with minor or with moderate injuries. It would seem that when one looks more closely at the types of injuries that occur, the fact that males have disproportionate minor accidents than female affects the results.

5.2. Risk Factors

Alcohol and drunk driving affect accident severity. In spite of being at the forefront of policy debates over recent decades, driving under the influence is still a social problem. Across all three samples, one finds that those drivers who had some alcohol (but not drunk), where more likely to have a severe injury. And if the driver were drunk, the likelihood of having a more severe accident doubles when compared to individuals who had consumed some alcohol. Interestingly, the effect of alcohol is more important for the older group than the younger group. In terms of numbers, the young are still more prone to both drink and drive (eight percent of the sample), and drive when drunk (seven percent of the sample) when compared to older drivers (one percent of the sample for both the presence of alcohol and being drunk), but when older people have an accident under the influence, they are much more likely to have a more severe injury when compared to the younger group.

Another relevant factor is the number of occupants in a vehicle (*occupants*). The idea here is that occupants may either unduly distract the driver, thus causing a more severe accident, or, they may be an extra set of eyes on the road, thus averting more serious accidents. My results suggest that the number of occupants has a negative impact on the severity of accidents; but the square of this number has the opposite effect. However, when one looks only at the young and old drivers, we find that it is only the squared term that matters – and for the young drivers it is positive but for the older drivers it is negative. Thus, the probability of a more severe accident is weakened by the number of people in the car when a young person is behind the wheel, but it is mitigated when an older person is behind the wheel. This result seems sensible, given two possible influences and consistent with the findings of Simons-Morton, Lerner and Singer (2005) and Weiss, Kaplan and Prato (2014).

I also interacted the age of the driver with the number of passengers to see the extent to which these two factors mattered together. Some interaction terms are statistically significant (for the age 16-20, 45-54, 65-74 and 75-84 groups) while the rest are not.

Finally, Figures 3 and 4 illustrate the marginal effect of adding one more occupant in the car on the likelihood of an injury of type i for the samples of young and senior drivers. What is remarkable to see right away, is the fact that for both groups, the likelihood of having either a fender bender (no injury) or a minor injury increases with the number of passengers which could be explained by driving distraction. However, once injuries before more severe, their likelihood falls with the number of occupants which could be explain by more eyes on the road or the slowing down of driving speed due to pressure from passengers. The confidence intervals for these figures are much smaller for the young groups (more precise estimates) when compared to the older groups.

The wearing of seatbelt has a negative and strong impact on the severity of an injury. Similarly, wearing a seatbelt and being in a vehicle with an air bag help to mitigate the severity of an injury. It is possible that the number of accident increases with seatbelt use because of the “Peltzman effect”, but the severity is clearly smaller with use.

Four driving factors (inattention, inexperience, failure to yield and being distracted) are important causes of accidents and reflect various aspects of distraction and driving failure (SGI 2014), but they are not always associated with more severe injuries. The first two factors that only matters for young drivers – with inattention being associated with more fender-bender type accidents (at the 10% level of significance) and inexperience associated with more severe injuries, but not older ones. Although “failure to yield” is one of the more common contributing factors reported in the data set (SGI 2014), this dummy variable does not have a statistical impact on injury type. Finally, being distracted is associated with less severe accidents for all but the older group – again suggesting an increasing likelihood of property-damage only accidents when distracted.

The type of vehicle that is driven affects the type of injury sustained. When compared to small trucks and SUVs, people who drive a passenger car are more likely to have more severe accidents. This finding is consistent with previous studies (White 2004; Li 2009).

5.3. Traffic Safety Policies

Several changes in policies affecting driver safety were implemented over the period of the data used in this paper. These include, graduated drivers’ licenses, driving under the influence rules, speed limit changes, and liability regulations.

Saskatchewan implemented a GDL policy in September, 2005. I include a dummy variable for this period forward. Not surprisingly, this policy is associated with a reduction in the severity of accident for young people in my sample. Similarly, the SAS policy (license suspension if driving under the influence) is associated with a reduction in the severity of accidents. The speed limit on major highways was increased from 100 kilometres an hour to 110 in June, 2003 – and is associated with more severe accidents.

There is a large literature that looks at the impact of liability rules on driving behaviour. I include a dummy variable for the switch to no-fault insurance in 1995 and find that this is associated with less severe accidents – a result which is at odds with most of the literature on this matter (e.g. Devlin 1999). However, because Saskatchewan was a public insurance regime even before it switched to a no-fault insurance, this may account for my result. Besides, people's response tends to vary according to the impact of policies and from period to period (Solof 2010). This question is worth looking at in more detail.

5.4. Driving Environments

Among all road conditions reported, only the ice-covered road is significantly positively correlated with severity of accidents for all samples, but it became insignificant for young and old drivers. With respect to other environment factors, various degrees of weather were found to be significantly correlated with the severity of accidents among all three samples; with the worst weather (reference group) leading to the most severe injuries. Old drivers do not seem to be as affected by bad weather when compared to the young sample, likely because of their driving experience.

Temporal variables are almost always significantly correlated with injury levels. Generally speaking, the year-specific trend has a slightly positive impact on accident injury severity for all drivers except old ones. A small positive number indicates the severity of accidents generally increased over the years.

Only the three beginning months of the year are associated with less severe injuries relative to December, while the other months tend to have severe accidents than December. In April, the probability of suffering severe accidents slightly increases for old drivers. July is the only insignificant month for all drivers, but it positively and statistically significantly increases the probability of severe accidents for both young and old drivers. The estimation results seem to suggest that summer months are associated with more severe injuries than winter ones. Of course, it is during the summer when one finds more leisure driving, which may account for this finding.

Driving at night tends to increase the injury level. Driving in rush hour tends to decrease the injury level, possibly because of the effect of slow speeds due to congestion. Older drivers are not affected by the time of the accident.

The dramatic effect of the property damage reporting threshold increase from \$1,000 to \$5,000 in 2010 is shown in Figure 1. Thus, it is possible that parameters in the regression are affected by a decrease in the aggregate number of accidents (because many fewer property-damage only accidents were then reported). Hence, I separately estimated the models with and without data after 2010 in order to test coefficient stabilities. Ideally, the coefficients of the two specifications are statistically the same with each other due because I had controlled for the 2010 reporting change with a dummy variable. Regression results support this assumption, with little alterations of most coefficients for key characteristics when comparing the 1990-2009 results with the 1990-2012 results. I use a non-linear t-test to test the significance of differences. Most coefficients have similar parameter values and significant levels before and after 2010, apart from a few pairs of coefficients such as inattention and distraction, which already differ in coefficient values and, especially, significance levels.

6. Conclusion and limitation

This paper uses detailed data on accidents on Saskatchewan roads in order to analyze the determinants of the severity of injuries to drivers. In contrast to previous work, this paper separately analyzes the severity of accidents for different age groups, in order to examine the different driving behaviors across young and old drivers. As a result, most of my findings are consistent with expectations from previous works but some are not.

This paper was mainly concerned with two questions: one pertaining to the riskiness of the young and old drivers, and the other on the impact of occupants in the vehicle on accident severity. My results suggest that the severity of accidents decreases with age; moreover, the impact of occupants in the vehicle is different for the young and the old. I found that the presence of passengers has a clearly adverse impact on minor accidents for the young, while this effect is much less significant for the older population. For both types of drivers, the probability of having a severe injury is lessened when passengers are in the car. Thus, the presence of passengers alters driver's behaviours.

There are several other important findings from the research. First, most of my findings concerning female drivers are contrary to previous research. I find that female drivers are more dangerous than male drivers, but male drivers have more accidents, which could alter the results. Second, driving after alcohol consumption is still a big problem of both young and old drivers. Considering the relative much less drinking and driving proportion of old drivers, sober and drunk old drivers are more dangerous because they tend to suffer more severe accidents than others. Third, I roughly prove the “offsetting behavior hypothesis” of safety equipment use among Saskatchewan drivers. Fourth, even SGI (2014) emphasized some prevalent factors, such as inattention, inexperience, distraction, these factors have insignificant impacts on old drivers. Finally, environments have less impact on old drivers. The last two findings imply us that old drivers have relative robust driving behaviours which need to be considered when policy-making.

My work enables me to identify and measure the effect of various accident factors on the severity of accident, and I especially illustrate precise pictures about how each number of age and occupant can affect the severity of accidents by marginal effect analysis. It is clear that young and old drivers have different driving behaviours and age-specific traffic safety policies could works better on target age groups: for example, different alcohol thresholds and different number of passenger limitations for young and old drivers. Besides, people’s preferences and behaviours tend to vary over years (Solof 2010), it is necessary to examine the policy effects from time to time.

Although the data set includes detail information of accidents so as I can analysis the determinants of accident severity, there are still some limitations stop me to look more precisely. First, the absence of damage cost of accidents makes me incapable of exact the pure effects of factors before and after property damage threshold changes. Second, the estimation results might be not that precisely without exact numbers of key factors. For example, actual speed and actual blood alcohol content (BAC) when accidents are usually reported together; even a lot of drivers claim whether they use safety restraints or not, there are still a large proportion of drivers and victims did not commit, estimation could be changed by those not reporting uses.

Reference

Abay, Kibrom A., Rajesh Paleti, and Chandra R. Bhat. (2013). "The Joint Analysis of Injury Severity of Drivers in Two-Vehicle Crashes Accommodating Seat Belt use Endogeneity." *Transportation Research: Part B: Methodological* 50: 74-89.

Al-Balbissi, Adli H. (2003). "Role of Gender in Road Accidents." *Traffic Injury Prevention* 4 (1): 64-73.

Anbarci, Nejat, Monica Escaleras, and Charles A. Register. (2009). "Traffic Fatalities: Does Income Inequality Create an Externality?" *Canadian Journal of Economics/Revue Canadienne D'Économique* 42 (1): 244-266.

Anderson, D. Mark, Benjamin Hansen, and Daniel I. Rees. (2013). "Medical Marijuana Laws, Traffic Fatalities, and Alcohol Consumption." *Journal of Law and Economics* 56 (2): 333-369.

Anderson, Michael. (2008). "Safety for Whom? the Effects of Light Trucks on Traffic Fatalities." *Journal of Health Economics* 27 (4): 973-989.

Brouwer, W. H., W. Waterink, P. C. Van Wolffelaar, and T. Rothengatter. (1991). "Divided Attention in Experienced Young and Older Drivers: Lane Tracking and Visual Analysis in a Dynamic Driving Simulator." *Human Factors* 33 (5): 573-582.

Carpenter, Christopher. (2006). "Did Ontario's Zero Tolerance and Graduated Licensing Law Reduce Youth Drunk Driving?" *Journal of Policy Analysis and Management* 25 (1): 183-195.

Carpenter, Christopher S. and Mark Stehr. (2008). "The Effects of Mandatory Seatbelt Laws on Seatbelt use, Motor Vehicle Fatalities, and Crash-Related Injuries among Youths." *Journal of Health Economics* 27 (3): 642-662.

Carpenter, Christopher and Carlos Dobkin. (2009). "The Effect of Alcohol Consumption on Mortality: Regression Discontinuity Evidence from the Minimum Drinking Age." *American Economic Journal: Applied Economics* 1 (1): 164-182.

Chaloupka, Frank J. and Adit Laixuthai. (1994). *Do Youths Substitute Alcohol and Marijuana? some Econometric Evidence*. Vol. w4662 National Bureau of Economic Research, Inc, NBER Working Papers: 4662.

Chang, K., C. C. Wu, and Y. H. Ying. (2012). "The Effectiveness of Alcohol Control Policies on Alcohol-Related Traffic Fatalities in the United States." *Accident Analysis & Prevention* 45: 406-415.

Chipman, Mary L., Carolyn G. MacGregor, Alison M. Smiley, and Martin Lee-Gosselin. (1992). "Time Vs. Distance as Measures of Exposure in Driving Surveys." *Accident Analysis & Prevention* 24 (6): 679-684.

Cohen, Alma and Rajeev Dehejia. (2004). "The Effect of Automobile Insurance and Accident Liability Laws on Traffic Fatalities." *Journal of Law and Economics* 47 (2): 357-393.

Cohen, Alma and Liran Einav. (2003). "The Effects of Mandatory Seat Belt Laws on Driving Behavior and Traffic Fatalities." *Review of Economics and Statistics* 85 (4): 828-843.

Cummins, J. David, Richard D. Phillips, and Mary A. Weiss. (2001). "The Incentive Effects of no-Fault Automobile Insurance." *Journal of Law and Economics* 44 (2): 427-464.

Dee, T. S. (1998). "Reconsidering the Effects of Seat Belt Laws and their Enforcement Status." *Accident; Analysis and Prevention* 30 (1): 1-10.

Devlin, R-A. (1997). *No-Fault Automobile Insurance and Accident Severity: Lessons Still to be Learned* University of Ottawa, Department of Economics, Working Papers.

Devlin, Rose Anne. 1992. "Liability Versus no-Fault Automobile Insurance Regimes: An Analysis of the Experience in Quebec." In *Contributions to Insurance Economics*, 499-520: Springer.

———. 1999. *No-Fault Automobile Insurance and Accident Severity: Lessons Still to be Learned*, edited by Georges Dionne, Claire Laberge-Nadeau eds Centre for Research on Transportation 25th Anniversary Series. Huebner International Series on Risk, Insurance, and Economic Security. Boston; Dordrecht and London: Kluwer Academic.

Devlin, Rose Anne, Reza Ghazal, and Victoria Barham. (2012). "The Effects of no-Fault and Choice Systems on Accident Severity: A Micro Level Analysis." .

Dissanayake, Sunanda and Indike Ratnayake. (2008). "Effectiveness of Seat Belts in Reducing Injuries: A Different Approach Based on KABCO Injury Severity Scale." *Journal of the Transportation Research Forum* 47 (4): 135-146.

———. (2006). "Identification of Factors Leading to High Severity of Crashes in Rural Areas using Ordered Probit Modeling." *Journal of the Transportation Research Forum* 45 (2): 87-101.

Doherty, Sean T., Jean C. Andrey, and Carolyn MacGregor. (1998). "The Situational Risks of Young Drivers: The Influence of Passengers, Time of Day and Day of Week on Accident Rates." *Accident Analysis & Prevention* 30 (1): 45-52.

Ehsani, Johnathon Pouya, C. Raymond Bingham, and Jean T. Shope. (2013). "The Effect of the Learner License Graduated Driver Licensing Components on Teen Drivers' Crashes." *Accident; Analysis and Prevention* 59: 327-336.

Garcia-ferrer, Antonio, Aránzazu De Juan, and Pilar Poncela. (2007). "The Relationship between Road Traffic Accidents and Real Economic Activity in Spain: Common Cycles and Health Issues." *Health Economics* 16 (6): 603.

Glendon, AI, L. Dorn, Davies, G. Matthews, and R. G. Taylor. (1996). "Age and Gender Differences in Perceived Accident Likelihood and Driver Competences." *Risk Analysis* 16 (6): 755-762.

Haglund, Mats and Lars Åberg. (2000). "Speed Choice in Relation to Speed Limit and Influences from Other Drivers." *Transportation Research Part F: Traffic Psychology and Behaviour* 3 (1): 39-51.

Jewell, R. Todd and Robert W. Brown. (1995). "Alcohol Availability and Alcohol-Related Motor Vehicle Accidents." *Applied Economics* 27 (8): 759-765.

Kockelman, Kara Maria and Young-Jun Kweon. (2002). "Driver Injury Severity: An Application of Ordered Probit Models." *Accident Analysis & Prevention* 34 (3): 313-321.

Kopits, Elizabeth and Maureen Cropper. (2005). "Traffic Fatalities and Economic Growth." *Accident Analysis & Prevention* 37 (1): 169-178.

Kreft, Steven F. and Nancy M. Epling. (2007). "Do Border Crossings Contribute to Underage Motor-Vehicle Fatalities? an Analysis of Michigan Border Crossings." *Canadian Journal of Economics* 40 (3): 765-781.

Kweon, Young-Jun and Kara M. Kockelman. 2010. "Driver Attitudes and Choices: Speed Limits, Seat Belt use, and Drinking-and-Driving.".

Levitt, Steven D. and Jack Porter. (2001). "How Dangerous are Drinking Drivers?" *Journal of Political Economy* 109 (6): 1198-1237.

Li, Shanjun. 2009*. Traffic Safety and Vehicle Choice*.

Lindo, Jason M., Peter Siminski, and Oleg Yerokhin. (2014). *Breaking the Link between Legal Access to Alcohol and Motor Vehicle Accidents: Evidence from New South Wales*. Vol. w19857 National Bureau of Economic Research, Inc, NBER Working Papers: 19857.

Loeb, Peter D. and William A. Clarke. (2007). "The Determinants of Truck Accidents." *Transportation Research: Part E: Logistics and Transportation Review* 43 (4): 442-452.

Long, J. Scott and Jeremy Freese. 2006. *Regression Models for Categorical Dependent Variables using Stata* Stata press.

Loughran, David S., Seth A. Seabury, and Laura Zakaras. 2007. *Regulating Older Drivers: Are New Policies Needed?* Rand Corporation.

McCarthy, Patrick. (2003). "Alcohol-Related Crashes and Alcohol Availability in Grass-Roots Communities." *Applied Economics* 35 (11): 1331-1338.

McCornac, Dennis C. (1993). "The Efficacy of Government Safety Policies on Traffic-Related Fatalities: Empirical Estimates from Japan." *Applied Economics* 25 (3): 409-412.

Morrisey, Michael A. and David C. Grabowski. (2011). "Gas Prices, Beer Taxes and GDL Programmes: Effects on Auto Fatalities among Young Adults in the US." *Applied Economics* 43 (25-27): 3645-3654.

Peltzman, Sam. (1975). "The Effects of Automobile Safety Regulation." *The Journal of Political Economy*: 677-725.

Perera, Loshaka and Sunanda Dissanayake. (2010). "Contributing Factors to Older-Driver Injury Severity in Rural and Urban Areas." *Journal of the Transportation Research Forum* 49 (1): 5-22.

Plataforma SINC. (2014). *Risk of Traffic Accident Injury Depends on Sex and Age, Spanish Study Finds
*. ScienceDaily: ScienceDaily.

Public Health Agency of Canada. (2012). *Injury in Review, 2012 Edition: Spotlight on Road and Transport Safety*. Ottawa, Ontario: Health Canada Publications. doi:HP15-14/2012E-PDF. www.parachutecanada.org/downloads/research/reports/InjuryInReview2012_EN.pdf;.

Ramage-Morin, Pamela L. (2008). "Motor Vehicle Accident Deaths, 1979 to 2004." .

Rhodes, Nancy and Kelly Pivik. (2011). "Age and Gender Differences in Risky Driving: The Roles of Positive Affect and Risk Perception." *Accident Analysis & Prevention* 43 (3): 923-931.

SGI. "2012 Saskatchewan Traffic Accident Facts.", accessed Nov/5, 2014, http://www.sgi.sk.ca/pdf/tais/TAIS_2012_Annual_Report.pdf.

Simons-Morton, Bruce, Neil Lerner, and Jeremiah Singer. (2005). "The Observed Effects of Teenage Passengers on the Risky Driving Behavior of Teenage Drivers." *Accident Analysis & Prevention* 37 (6): 973-982.

Solof, Mark. "Behavioral Economics Offers Insights and Strategies for Improving Transportation." Intransitionmag.org, accessed Nov/16, 2014, http://www.intransitionmag.org/Spring-Summer_2010/behavioral_economics_and_transportation.aspx.

Statistics Canada. "Leading Causes of Death, Total Population, by Age Group and Sex, Canada 2009 [CANSIM Table 102-0561].", accessed July/25, 2012, www.statcan.gc.ca/pub/84-215-x/84-215-x2012001-eng.htm.

Transport Canada. (2013). *Canadian Motor Vehicle Traffic Collision Statistics: 2012*.

———. (2011). *Road Safety in Canada*. http://www.tc.gc.ca/eng/motorvehiclesafety/tp-tp15145-1201.htm ed.

Traynor, Thomas L. (2009). "The Impact of State Level Behavioral Regulations on Traffic Fatality Rates." *Journal of Safety Research* 40 (6): 421-426.

Turcotte, Martin. (2012). "Profile of Seniors' Transportation Habits." *Can Soc Trends* 93: 1-16.

Weiss, Harold B., Sigal Kaplan, and Carlo G. Prato. (2014). "Analysis of Factors Associated with Injury Severity in Crashes Involving Young New Zealand Drivers." *Accident; Analysis and Prevention* 65: 142-155.

White, Michelle J. (2004). "The "Arms Race" on American Roads: The Effect of Sport Utility Vehicles and Pickup Trucks on Traffic Safety*." *Journal of Law and Economics* 47 (2): 333-355.

Williams, AF and Daniel Richard Mayhew. 2004. *Graduated Licensing: A Blueprint for North America*.

Williams, Allan F., Susan A. Ferguson, and Anne T. McCartt. (2007). "Passenger Effects on Teenage Driving and Opportunities for Reducing the Risks of such Travel." *Journal of Safety Research* 38 (4): 381-390.

Williams, Allan F. and Veronika I. Shabanova. (2002). "Situational Factors in Seat Belt use by Teenage Drivers and Passengers." *Traffic Injury Prevention* 3 (3): 201-204.

Wood, J. M. and K. Mallon. (2001). "Comparison of Driving Performance of Young and Old Drivers (with and without Visual Impairment) Measured during in-Traffic Conditions." *Optometry and Vision Science : Official Publication of the American Academy of Optometry* 78 (5): 343-349.

Ye, Fan and Dominique Lord. (2014). "Comparing Three Commonly used Crash Severity Models on Sample Size Requirements: Multinomial Logit, Ordered Probit and Mixed Logit Models." *Analytic Methods in Accident Research* 1: 72-85.

Figures

Figure 1 Numbers of accidents by injury level: 1991-2012 Saskatchewan

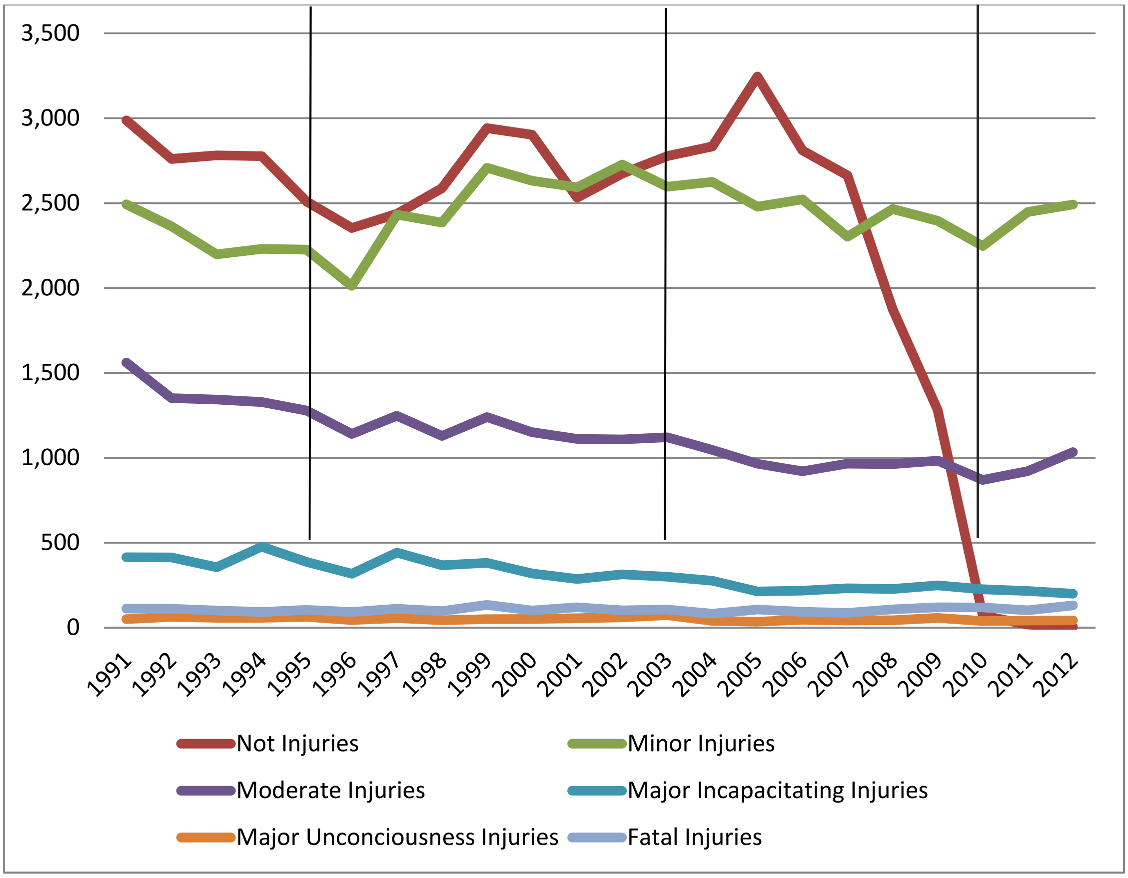
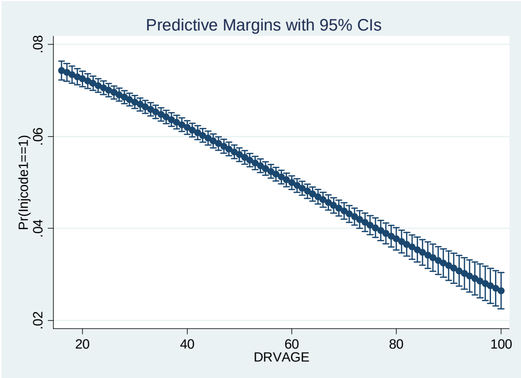
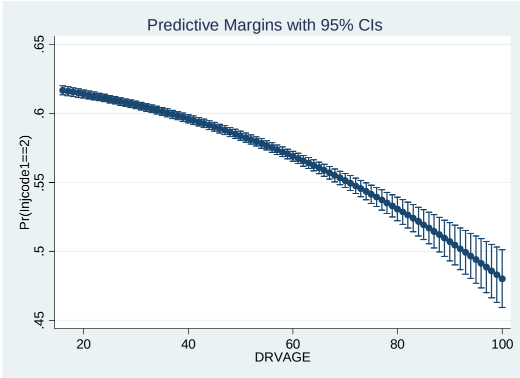


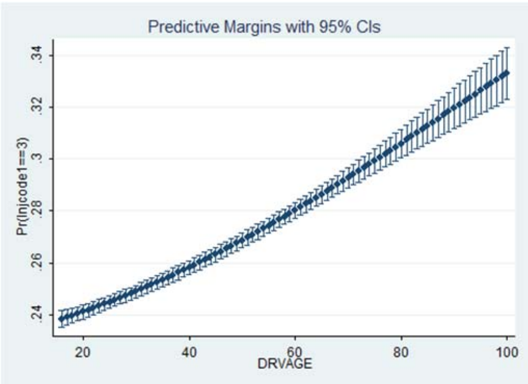
Figure 2 Marginal effects of driver's age on injury categories.



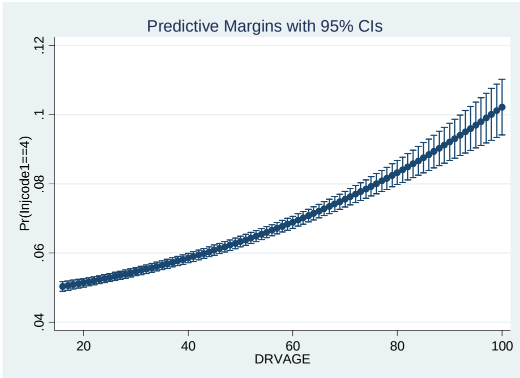
(a) No injuries



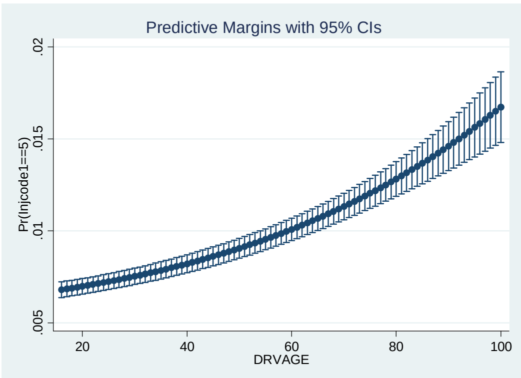
(b) Minor



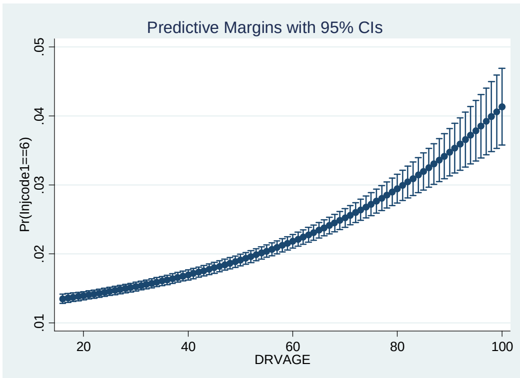
(c) Moderate



(d) Incapacitating

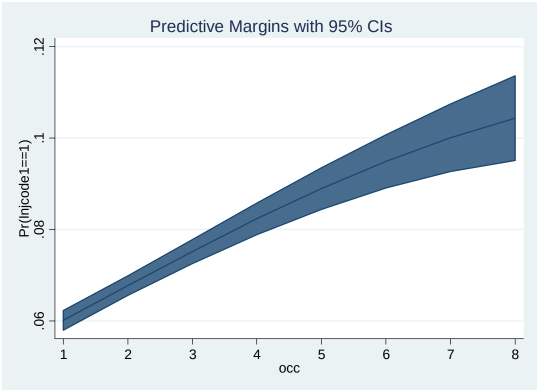


(e) Unconscious

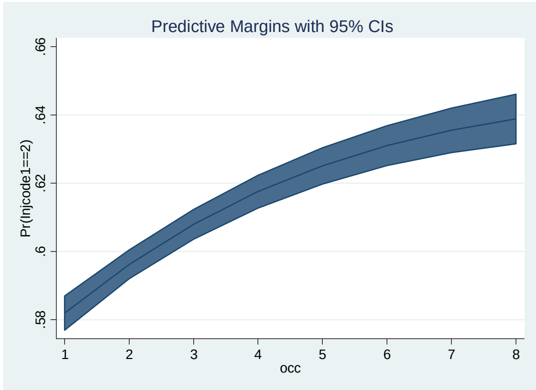


(f) Fatal

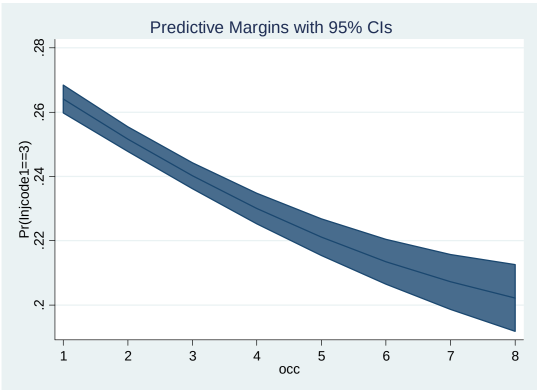
Figure 3 Marginal effects of number of occupants in vehicle, young group



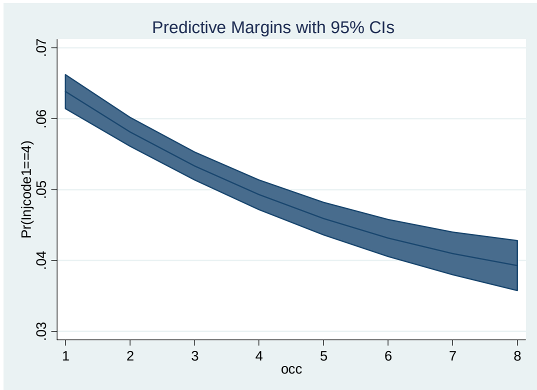
(a) No injuries



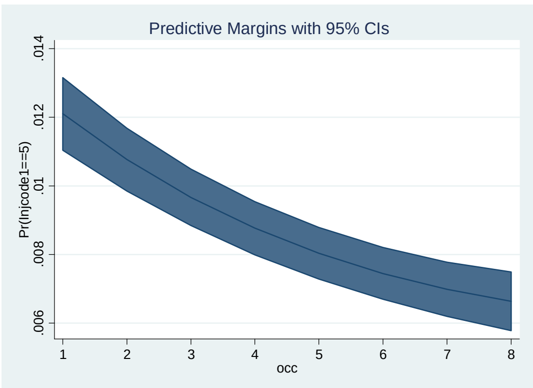
(b) Minor



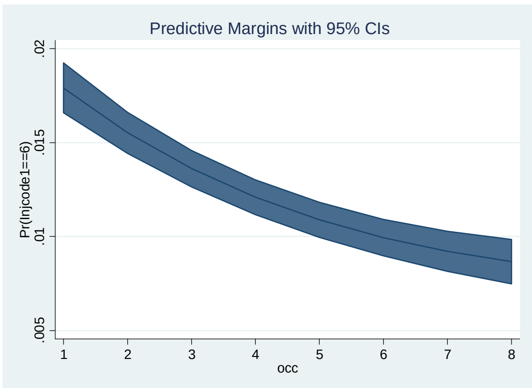
(c) Moderate



(d) Incapacitating

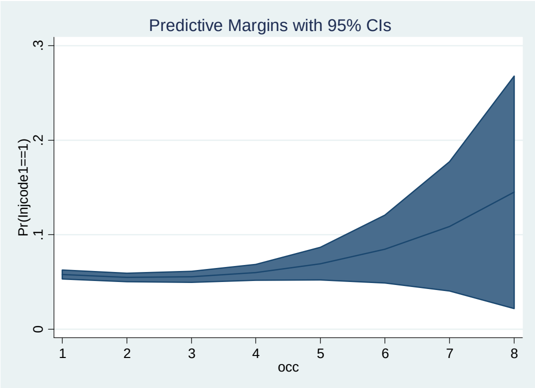


(e) Unconscious

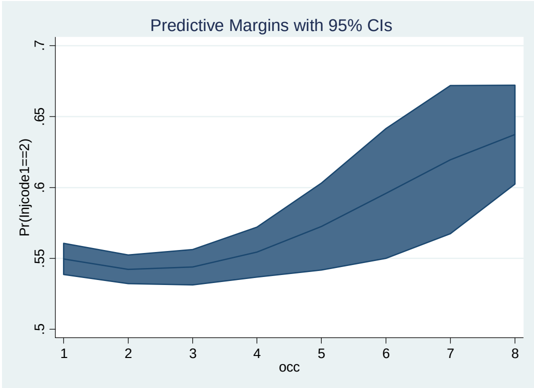


(f) Fatal

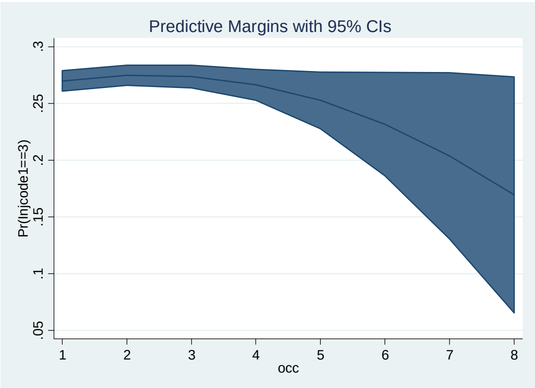
Figure 4 Marginal effects of number of occupants in vehicle, old group



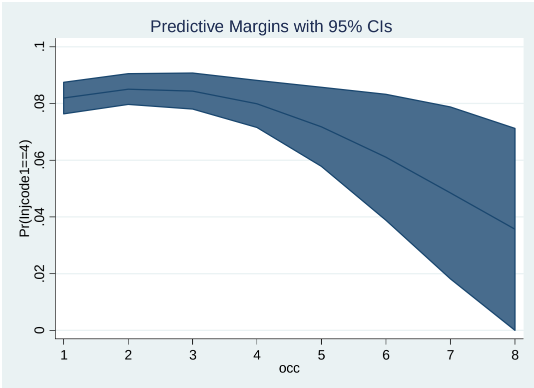
(a) No injuries



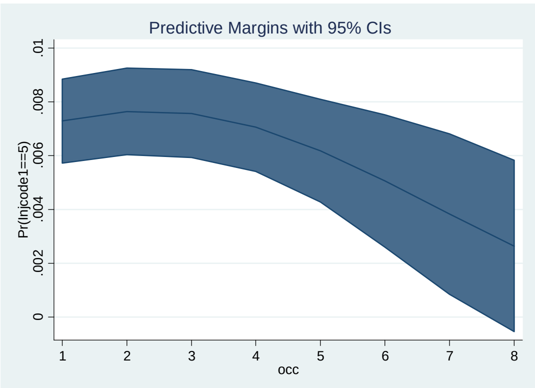
(b) Minor



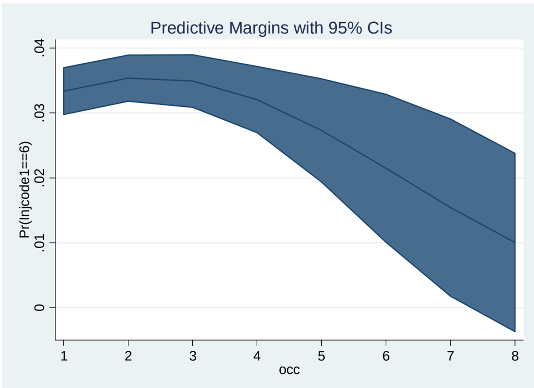
(c) Moderate



(d) Incapacitating



(e) Unconscious



(f) Fatal

Tables

Table 1 Variable names and definitions

Variable	Description
Dependent variable	
Injury level	6 categories: 1 = Not injured; 2 = minor injuries; 3 = moderate non-incapacitating injuries; 4 = major incapacitating injuries; and 5 = major unconscious injuries; 6 = fatal injuries sustained by drivers.
Independent variables	
Driver's characteristics	
Age	Driver's age
Agesq	Driver's age squared
Age1620	1 = if the driver is 16-20 years old, 0 = otherwise
Age2124	1 = if the driver is 21-24 years old, 0 = otherwise
Age2534	1 = if the driver is 25-34 years old, 0 = otherwise
Age3544	1 = if the driver is 35-44 years old, 0 = otherwise, **reference group**
Age4554	1 = if the driver is 45-54 years old, 0 = otherwise
Age5564	1 = if the driver is 55-64 years old, 0 = otherwise
Age6574	1 = if the driver is 65-74 years old, 0 = otherwise
Age7584	1 = if the driver is 75-84 years old, 0 = otherwise
Age85	1 = if the driver is over 85 years old, 0 = otherwise
Female	Driver is a female.
Female*age1620	1 = if the driver is female and 16-20 year olds, 0 = otherwise
Female*age2124	1 = if the driver is female and 21-24 year olds, 0 = otherwise
Female*age2534	1 = if the driver is female and 25-34 year olds, 0 = otherwise
Female*age3544	1 = if the driver is female and 35-44 year olds, 0 = otherwise, **reference group**
Female*age4554	1 = if the driver is female and 45-54 year olds, 0 = otherwise
Female*age5564	1 = if the driver is female and 55-64 year olds, 0 = otherwise
Female*age6574	1 = if the driver is female and 65-74 year olds, 0 = otherwise
Female*age7584	1 = if the driver is female and 75-84 year olds, 0 = otherwise
Female*age85	1 = if the driver is female and over 85 year olds, 0 = otherwise
Driver's behavior	
Alcohol	1 = the driver consumed alcohol but under legal limitation, 0 = otherwise
Drunk	1 = the driver consumed alcohol and over legal limitation, 0 = otherwise
Occupants	Number of occupants including the driver in the driver's car

Occupantssq	Number of occupants squared
Occ*age	The interaction variable of occupant and driver's age
Occ*age1620	Number of occupants in car when the driver is 16-20 years old
Occ*age2124	Number of occupants in car when the driver is 21-24 year olds,
Occ*age2534	Number of occupants in car when the driver is 25-34 year olds,
Occ*age3544	Number of occupants in car when the driver is 35-44 year olds, **reference group**
Occ*age4554	Number of occupants in car when the driver is 45-54 year olds
Occ*age5564	Number of occupants in car when the driver is 55-64 year olds,
Occ*age6574	Number of occupants in car when the driver is 65-74 year olds,
Occ*age7584	Number of occupants in car when the driver is 75-84 year olds,
Occ*age85	Number of occupants in car when the driver is over 85 year olds,
Seatbelt	1 = seatbelt is properly used, 0= otherwise
Airbag	1 = seatbelt and air bag are properly used, 0= otherwise
Inattention	1 = the driver didn't pay enough attention to driving task, 0 = otherwise
Distract	1=the driver was distracted by any condition or activity inside or outside the vehicle, 0=otherwise
Inexperience	1=accident caused due to driver's lack of traffic experience in this situation, 0=otherwise
Fail to yield	1=the driver failed to yield the right-of-way, 0=otherwise
Speeding	1=driving too fast for that specific road condition, 0=otherwise
Vehicle characteristics	
Car	1 = driver is driving a car when accident, 0 = otherwise.
Trucks	1 = driver is driving a truck or pickup or SUV when accident, 0 = otherwise, **reference group**
Highway	Increase in speed limit for rural four-lane highways, 1 = highway accidents after June 1st 2003, 0 = otherwise
Traffic Policies	
GDL	Graduate driver licensing system, 1 = accident happened in2005-2011, 0 = otherwise
SAS	Short-term administrative suspension program, 1 = accidents from August 1996, 0 = otherwise
Choice	No-fault insurance system, 1 = 1995-2002, 0 = other years
No fault	Choice insurance system, 1 = 2003-2011, 0 = other years
Dumreporting93	SGI increased property damage threshold ($500 to$1,000), 1 = 1993-2002, 0 = otherwise
Dumreporting02	SGI removed property damage threshold and implemented a choice system, 1 = 2002-2009, 0 = otherwise
Dumreporting10	SGI increased property damage threshold ($1,000 to $5,000), 1 = 2010-2012, 0 = otherwise

Actual Road characteristics	
Dry	1 = the road surface was dry, 0 = otherwise
Ice	1 = the road surface was covered by ice or solid snow, 0 = otherwise
Wet	1 = the road surface was wet, 0 = otherwise
Actual Road characteristics	
Clear	1 = the weather was clear, 0 = otherwise
Cloudy	1 = the weather was cloudy 0 = otherwise
Snow	1 = it was snowing when accident happened, 0 = otherwise
Rain	1 = it was raining when accident happened, 0 = otherwise
Temporal characteristics	
Year	The 4-digit year of accident happened from 1990-2012, trend
Yearsq	Year squared
Month	The month of accident happened from January to December (12 categories) Dec is the **reference group**
Night	1 = time between 10 p.m. to 6 a.m., 0 = otherwise
Rush hour	1 = time between 4 p.m. to 6 p.m., 0 = otherwise

Table 2 Means of Variables

Variables	All			Young (age≤24)			Old (age≥65)		
	Male	Female	Total	Male	Female	Total	Male	Female	Total
Personal characteristics									
N	74,086	62,645	136,731	27,372	22,913	50,285	7,780	3834	11,614
Gender (%)	54	46	--	54	46	--	67	33	--
Average age	36.86	35.08	36.04	19.66	19.49	19.58	74.01	73.03	73.69
Average occupants	2.20	2.04	2.16	2.48	2.18	2.34	1.87	1.59	1.78
Number of vehicle involved in the accidents									
Average	1.77	1.83	1.80	1.61	1.74	1.67	1.94	1.88	1.92
Single (%)	19	13	32	26	17	43	13	7	20
Double (%)	31	28	59	25	25	50	47	23	70
Severity of injury									
Average level	2.44	2.36	2.40	2.41	2.34	2.38	2.56	2.51	2.54
Not injured (%)	4	2	6	4	3	7	5	1	6
Minor (%)	31	29	60	31	29	60	35	19	54
Moderate (%)	14	12	26	13	11	24	18	8	26
Incapacitating (%)	4	2	6	4	2	6	6	3	9
Unconscious (%)	0.6	0.2	0.8	0.7	0.3	1	0.6	0.2	0.8
Fatal (%)	1.2	0.5	1.7	1.6	0.4	2	3	1	4
Types of vehicles									
Car (%)	32	33	65	31	33	64	31	33	64

Trucks (%)	22	12	34	23	12	35	24	12	36
Use of Safety equipment									
Proper use (%)	48	42	90	44	42	86	64	32	96
Seatbelt (%)	43	37	80	40	38	78	56	28	84
Seatbelt + airbag (%)	5	5	10	4	4	8	8	4	12
Improper use (%)	7	3	10	10	4	14	3	1	4
Major risky factors									
Inattentiveness (%)	10	7	17	11	8	19	16	9	25
Fail to yield (%)	4	3	7	4	3	7	11	6	17
Inexperience (%)	3	4	7	7	9	16	4	3	6
Reason by legally drunk (%)	4	1	5	6	2	8	0.8	0.2	0.9
Reason by alcohol (%)	3	1	4	6	2	8	0.6	0.1	0.7
Distraction (%)	2	2	4	2	2	4	2	1	3
Most accidents happened in									
Rush hour (4-6p.m.) (%)	8	8	16	6	7	13	11	6	17
Summer (Jun, Jul, Aug) (%)	15	12	27	16	12	28	19	10	29
Environment conditions									
Good weather (%)	34	29	63	36	30	66	43	22	65
Good road condition (%)	50	41	91	50	40	90	63	31	94
Night (10p.m.-4a.m.)	11	6	17	18	9	27	3	1	4

Table 3 Distribution of injury level on gender

	Injury levels						
Gender	**No**	**Minor**	**Moderate**	**Incapacitating**	**Unconscious**	**Fatal**	**Total**
Male	5,438	42,420	18,918	4,839	770	1,701	74,086
(%)	4	31	14	4	0.6	1.2	54
Female	3,197	39,554	16,007	2,905	328	654	62,645
(%)	2	29	12	2	0.2	0.5	46
Total	8,635	81,974	34,925	7,744	1,098	2,355	136,731
(%)	6	60	26	6	0.8	1.7	100

Table 4 Ordered probit model results for three age groups: all, young and old

Variables	Full sample (1)		Full sample (2)		age<=25 (3)		age>=65 (4)	
Injury level	**coef**	**t-stat**	**coef**	**t-stat**	**coef**	**t-stat**	**coef**	**t-stat**
Personal Characteristics								
Driver's age								
Age	1.24e-3	(1.17)			0.11***	(3.54)	0.09**	(2.46)
Agesq	3.34e-5***	(3.23)			-2.18e-3***	(-2.99)	-4.85e-4**	(-2.06)
Age1620			-0.16***	(-7.59)				
Age2124			-0.05**	(-2.05)				
Age2534			-0.05**	(-2.52)				
Age4554			-0.01	(-0.50)				
Age5564			0.03	(1.06)				
Age6574			-0.01	(-0.24)				
Age7584			0.10*	(1.79)				
Age85			0.49***	(4.16)				
Driver's gender and interaction variables								
Female	0.05***	(3.58)	0.01	(0.36)	0.13*	(1.88)	0.77***	(3.03)
Female*age	-9.47e-4**	(-2.56)			-4.57e-3	(-1.27)	-0.01***	(-2.88)
Female*age1620			0.05***	(2.73)				
Female*age2124			0.01	(0.61)				
Female*age2534			-0.01	(-0.55)				
Female*age4554			0.02	(0.69)				
Female*age5564			-0.01	(-0.45)				
Female*age6574			0.06*	(1.80)				

Variables	Full sample (1)		Full sample (2)		age<=25 (3)		age>=65 (4)	
Injury level	**coef**	**t-stat**	**coef**	**t-stat**	**coef**	**t-stat**	**coef**	**t-stat**
Female*age7584			-0.04	(-0.89)				
Female*age85			-0.28***	(-2.64)				
Risk Factors								
Alcohol	0.23***	(13.11)	0.23***	(12.96)	0.21***	(9.67)	0.36**	(2.38)
Drunk	0.42***	(26.07)	0.42***	(25.87)	0.41***	(18.03)	0.55***	(4.42)
Occupants	-0.11***	(-13.84)	-0.10***	(-14.60)	-0.03	(-1.10)	0.17	(0.99)
Occupantssq	0.01***	(8.00)	4.40e-3***	(7.36)	3.06e-3***	(4.76)	-0.02*	(-1.90)
Occ*age	0.6e-3***	(3.51)			-2.00e-3	(-1.40)	-1.25e-3	(-0.58)
Occ*age1620			0.01*	(1.77)				
Occ*age2124			-0.01	(-0.53)				
Occ*age2534			0.01	(0.72)				
Occ*age4554			0.02**	(2.28)				
Occ*age5564			0.01	(1.14)				
Occ*age6574			0.07***	(3.98)				
Occ*age7584			0.11***	(4.21)				
Occ*age85			-0.08	(-1.30)				
Seat belt	-0.69***	(-54.72)	-0.69***	(-54.63)	-0.65***	(-37.58)	-0.94***	(-15.55)
Seatbelt + Airbag	-0.50***	(-32.53)	-0.50***	(-32.46)	-0.50***	(-21.54)	-0.73***	(-10.99)
Car	0.03***	(3.73)	0.02***	(3.58)	0.01	(0.88)	0.03	(1.34)
Highway	0.35***	(32.57)	0.35***	(32.58)	0.32***	(17.29)	0.43***	(12.55)
Inattention	0.01	(0.67)	0.01	(0.70)	-0.02*	(-1.67)	0.03	(1.12)
Inexperience	0.01	(1.17)	0.02	(1.21)	0.03**	(2.04)	0.02	(0.38)
Fail to yield	0.01	(0.69)	0.01	(0.54)	4.32e-3	(0.21)	0.04	(1.20)

Variables	Full sample (1)		Full sample (2)		age<=25 (3)		age>=65 (4)	
Injury level	**coef**	**t-stat**	**coef**	**t-stat**	**coef**	**t-stat**	**coef**	**t-stat**
Speeding	0.09***	(7.92)	0.09***	(7.93)	0.07***	(4.23)	0.27***	(4.60)
Distract	-0.05***	(-2.80)	-0.05***	(-2.81)	-0.09***	(-3.62)	-0.02	(-0.30)
Traffic Safety Policies								
GDL	-0.24***	(-16.51)	-0.24***	(-16.43)	-0.27***	(-10.96)		
SAS	-0.22***	(-13.45)	-0.22***	(-13.41)	-0.27***	(-10.12)	-0.04	(-0.86)
Choice	0.29***	(12.71)	0.29***	(12.65)	0.35***	(9.03)	-0.06	(-1.11)
No fault	-0.14***	(-8.51)	-0.14***	(-8.46)	-0.15***	(-5.82)	-0.04	(-0.71)
Dumreporting93	0.13***	(11.83)	0.12***	(11.80)	0.09***	(5.27)	0.10***	(2.69)
Dumreporting02	-0.64***	(-17.72)	-0.63***	(-17.65)	-0.74***	(-12.38)	-0.27***	(-2.74)
Dumreporting10	-0.60***	(-14.61)	-0.59***	(-14.54)	-0.69***	(-10.33)	-0.27**	(-2.29)
Driving Environment								
Actual road condition								
Dry	0.02	(1.20)	0.02	(1.23)	0.03	(1.02)	0.02	(0.34)
Ice	0.09**	(2.52)	0.09**	(2.56)	0.05	(0.91)	-0.04	(-0.32)
Wet	-5.58e-4	(-0.03)	-2.10e-5	(-1.15e-3)	-0.03	(-0.83)	0.06	(0.91)
Actual weather condition								
Clear	-0.08***	(-6.18)	-0.08***	(-6.21)	-0.06***	(-2.88)	-0.09**	(-2.08)
Cloudy	-0.10***	(-6.93)	-0.10***	(-6.95)	-0.08***	(-3.36)	-0.10**	(-2.22)
Snow	-0.10***	(-5.68)	-0.10***	(-5.72)	-0.11***	(-3.59)	-0.11*	(-1.74)
Rain	-0.10***	(-5.19)	-0.10***	(-5.23)	-0.11***	(-3.56)	-0.09	(-1.40)
Temporal conditions								
Year	0.04***	(18.38)	0.04***	(18.31)	0.05***	(13.12)	0.01	(1.48)
Jan	-0.06***	(-4.01)	-0.06***	(-3.99)	-0.03	(-1.08)	-0.08	(-1.55)

Variables	Full sample (1)		Full sample (2)		age<=25 (3)		age>=65 (4)	
Injury level	**coef**	**t-stat**	**coef**	**t-stat**	**coef**	**t-stat**	**coef**	**t-stat**
Feb	-0.08***	(-5.37)	-0.08***	(-5.40)	-0.09***	(-3.56)	-0.06	(-1.25)
Mar	-0.05***	(-3.22)	-0.05***	(-3.25)	-0.02	(-0.71)	-0.06	(-1.10)
Apr	0.06***	(4.02)	0.06***	(4.07)	0.06**	(2.43)	0.16***	(3.04)
May	0.06***	(4.06)	0.06***	(4.06)	0.06**	(2.37)	0.11**	(2.16)
Jun	0.04**	(2.48)	0.04**	(2.47)	0.07***	(2.83)	0.04	(0.92)
Jul	0.02	(1.55)	0.02	(1.60)	0.04*	(1.79)	0.09*	(1.86)
Aug	0.07***	(5.17)	0.07***	(5.17)	0.10***	(4.19)	0.07	(1.39)
Sep	0.10***	(6.75)	0.10***	(6.76)	0.12***	(4.82)	0.10**	(2.17)
Oct	0.12***	(8.99)	0.12***	(9.04)	0.15***	(6.12)	0.13***	(2.86)
Nov	0.04***	(2.86)	0.04***	(2.83)	0.07***	(2.80)	0.09**	(1.97)
Night	0.05***	(5.16)	0.05***	(5.01)	0.02*	(1.70)	-0.02	(-0.37)
Rush hour	-0.03***	(-3.04)	-0.02***	(-3.00)	-0.05***	(-3.32)	-0.03	(-1.23)
Constant cut1	84.22***	(17.91)	83.78***	(17.81)	99.18***	(12.99)	20.36	(1.59)
Constant cut2	86.24***	(18.34)	85.81***	(18.25)	101.18***	(13.25)	22.26*	(1.74)
Constant cut3	87.27***	(18.56)	86.84***	(18.46)	102.20***	(13.38)	23.19*	(1.81)
Constant cut4	87.89***	(18.69)	87.46***	(18.60)	102.81***	(13.46)	23.81*	(1.86)
Constant cut5	88.07***	(18.73)	87.64***	(18.63)	103.05***	(13.49)	23.91*	(1.86)
Observations	136,731		136,731		50,285		11,614	

Notes:

Robust t-statistics are in parentheses

1,5 and 10% levels of significance are denoted by***, ** and *, respectively.

Constant cuts are the thresholds in equation (3), respectively.