Impacts of Graduated Driver Licensing Regulations

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September 2019

Abstract

We evaluate the impact of the Graduated Driver Licensing (GDL) system introduced in Victoria, Australia as they influence both injury and fatality rates. Since 1990, the Victorian GDL scheme has undergone several modifications including the introduction of new requirements and the stricter enforcement of existing regulations. Our evaluation of the GDL is based on monthly mortality and morbidity data for drivers 18 to 25 for the period January 2000 to June 2017. We estimate the immediate and long-term impacts of each policy change to the GDL system.

Our results indicate that several initiatives in the GDL system have had impacts on both fatalities and injuries requiring hospitalisation when differentiated by gender. In a number of cases we observe that reactions to these measures are common to both genders. These include: the signalling of the proposed GDL changes in the media, the introduction of an extra probationary year for those under 21, the total alcohol ban for the entire probationary period, and limits on peer passengers for the first year. Stricter mobile phone restrictions appears to have had no impact on injuries for either males or females although they were associated with lower fatality rates for both. In addition, we found an indication that in the period prior to the introduction of the mandatory requirement of 120 hours supervised driving, there was a rise in male driver injuries possibly caused by a rush of more inexperienced learners to obtain their probationary licence.

Key words: young drivers, fatalities, injuries requiring hospitalisation, logbooks, passenger restrictions, intermediate licence, Poisson regression, gender differences, anticipation of policy changes

Declarations of interest: none

1. Introduction

The injury rate of young drivers has been estimated to be 5 to 10 times higher than for the safest age group (Elvik 2010). In addition, young male drivers tend to have a higher injury rate than young female drivers. For Australian drivers aged between 15 and 24, the road traffic death rates for male drivers was 3 times higher than for the equivalent population of female drivers (Australian Institute of Health and Welfare 2017). It has also been found that the highest period of risk for Australian young drivers is shortly after obtaining a licence until age 24 (VicRoads 2017). To respond to these facts many jurisdictions have introduced graduated driver licensing (GDL) systems to help to better prepare young drivers.

GDL systems aim to reduce crash risk for novice drivers and they appear to have had some success. For example, Newstead and Scully (2013) found the introduction of a new GDL system in Queensland in 2007 was associated with a 30% reduction in fatal crashes and a 13% reduction in fatal and serious injury crashes combined. The GDL system typically requires new drivers to progress through a series of stages before being granted a full driver's licence (see e.g. Williams, Tefft and Grabowski 2012, Bates et al 2014a, Senserrick and Williams 2015, Williams, McCartt and Sims 2016, Bates, Filtness and Watson 2018).

The Australian state of Victoria introduced its first GDL system in 1990 (Haworth 1994). The main features of this GDL included: minimum age for learner's permits, passing practical and theory tests, display of provisional ("P") plates for 3 years, minimum age of 21 for full licence, and vehicle power restrictions. During the 2000's six revisions to the program were made that consisted of a combination of new activities as well as stricter compliance regulations. However, because these changes were often introduced simultaneously, the separation of the individual contributions of each aspect of the GDL is made more difficult. In Section 2 we review previous literature to examine how the separate contributions of the various changes made to the GDL system in Victoria have been shown to affect crash rates.

To model the impact of the revisions to the GDL system we use two different sets of monthly traffic crash data for drivers 18 to 25 for the period January 2000 to June 2017. The first set of data include observations on claims involving hospitalisation while the second set provides observations on fatalities. In Section 3 we discuss the properties of the data. In Section 4 we outline the two models that we estimate. The first model accounts for the immediate impact of each policy change. However, since the impacts of policy changes may diminish over time, the second model includes up to 5 unrestricted lags for each policy change. In section 5 we estimate the models for both sets of data. Based on the previous research, we estimate separate models for young male and female drivers. Section 6 discusses the results and the final section presents conclusions.

2. Literature Review

From 2002 to 2014 there were six revisions made to the Victorian GDL program as instituted in 1990. Details of each of the revisions are outlined in Table 1. While in most cases the revisions to the GDL system involved the simultaneous introduction of new elements or modifications, the key elements of the revisions included: the introduction of harsher sanctions for speeding traffic offences, a mandated number of hours of supervised driving, extended learner period, the compulsory completion of a logbook, peer passenger restrictions, mobile phone restrictions, a new drive test, a longer period of zero blood alcohol concentration limits and restricted access to high-powered vehicles. In this section we review previous literature to examine how each of these key elements have been shown to affect crash rates. We also review previous research that has shown that females and males have some differences in driving behaviour and attitudes that may impact on their crash risk.

2.1 Increasing the severity of sanctions

Hagge and Marsh (1988) found that introducing increasing severe sanctions for repeated traffic offences for young drivers was associated with significant general and specific deterrent effects on subsequent behaviour and crashes.[1] Based on an examination of data for novice drivers in the Canadian province of British Columbia, Cooper, Pinili and Chen (1995) found that some form of sanction applied following an initial traffic offence could potentially reduce the subsequent probability of crash involvement by over 40 percent.

[1] If a potential offender refrains from committing a crime because they have observed others being punished for offending or they have been warned through media campaigns this is referred to as general deterrence. In contrast, if an individual who has previously been sanctioned for committing a crime then refrains from offending again for fear of further punishment this is referred to as specific deterrence.

Table 1: Summary of Revisions

	Date	Policy Changes
1	*Dec 2002*	• A lower demerit point threshold was introduced. P-plate (provisional) and L-plate (learner) drivers would lose their licence if they accumulated more than 5 demerit points in a 12-month period.[2] • P-plate drivers would lose their licence for 3 months and for every 4 additional points would be off the road for a further month
2	*Jan 2007*	• All drivers under the age of 26 were required to carry a licence or receive an on the spot fine. • Alcohol interlock measures for probationary drivers under the age of 26 found to be guilty of drink driving were also required as a condition of licence restoration.
3	*July 2007*	• Learner drivers were required to hold a learner permit for a minimum of 12 months, and it was also a requirement that the permit be carried while driving. • Learner drivers were now required to obtain a minimum of 120 hours of on-road supervised driving experience for those aged under 21 years at the time of licensing, including 10 hours at night. • A ban on the use of any mobile phone for learner drivers was introduced as well as new high-powered vehicle restrictions for probationary drivers. •A new definition of high-powered cars was introduced that prevented newly licensed drivers from driving a car with a V8 engine or a car with a turbocharger or supercharger.
4	*July 2008*	•A new 30-minute drive test that was specifically designed to assess learner drivers with high levels of supervised experience (Cavallo and Oh 2008). • The probationary period now included a 2-stage probationary licence system for at least 4 years which consisted of 12 months on a red P-plate (P1) and 3 years on a green P Plate (P2) for those aged under 21 years at the time of licensing. Those licensed at 22 years or over moved straight to P2. •Probationary drivers were required to be alcohol free for the entire probationary period. • Additional restrictions were placed on P1 drivers. They were banned from any mobile phone use (this included hands-free devices) •P1 drivers were restricted to carrying no more than one peer passenger (16-21) who were not a family member. •P-plate drivers were banned from towing unless for work or under instruction. •A good driving record was required to graduate from P1 to P2 and from P2 to a full licence.
5	*Nov 2013*	•A total ban on mobile/cell phone use for all P-plate drivers was introduced.
6	*July 2014*	•Victoria's probationary prohibited vehicle restrictions were modified to align with New South Wales, Queensland and South Australia. This resulted in a loosening of the power restriction on P-plate drivers to remove the previous blanket ban on the use of eight-cylinder, turbo and supercharged vehicles for vehicles manufactured from 1 January 2010.

[2] Demerit points are allocated to drivers who are found to be in breach of traffic regulations. More demerit points are given for more serious offences. For example, the higher the speed over the speed limit would accumulate more points.

2.2 Mandated hours supervised driving

Bates, Watson and King (2010) compared the amount of practice that learners in two Australian states report undertaking. At the time of the study learners in New South Wales were required to undertake 50 hours of supervised practice while learners in Queensland were not. They concluded that while this requirement may increase learners' average amount of hours of practice, it may also serve to discourage them from obtaining additional practice above the requirement. Siskind, Faulks and Sheehan (2019) examined the lengthening of the mandatory number of supervised hours for learner drivers from 50 to 120 hours in New South Wales and concluded that requiring more than 50 hours seemed to have few road safety benefits when introduced within an already rigorous and comprehensive set of driving licensing regulations. Gregersen et al. (2000) found that Swedish novice drivers who self-selected to accumulate close to 120 hours of supervised driving on average had a substantially lower crash rate of approximately 40% once licensed.

The age when learners obtain their learner permit may be important. In 2007, Victoria introduced 120 hours mandatory minimum of supervised practice for learners. Using the Victorian Learner Monitor survey, Meyer et al. (2015) found that those aged 16 years when they acquired their learner permit averaged 137 hours in 2014 and those aged 17 years averaged 127 hours. In comparison, learners who acquired their permits at 18 years or older in 2014 only averaged 88 hours.

Parental awareness of supervised hours requirements may also be important. O'Brien et al. (2013) found no change in fatal and injury crash involvement of 16-17 year old drivers in Minnesota following a 30 hour supervised driving requirement. However, telephone interviews with parents of newly licensed teenage drivers in five states including Minnesota revealed limited awareness of supervised driving requirements.

Simons-Morton's (2007) review of the literature concluded that requiring new drivers to complete a certain amount of practice driving may result in them taking longer to get licensed so that they will be older and more mature at licensure. Delaying licensure may have impact on crashes. Research in the UK has shown that while new drivers of any age have an elevated risk of involvement in a crash, young new drivers have the highest initial risk (Maycock 2002).

2.3 Increasing time to hold learners permit

Gregersen et al. (2000) found that lowering the age for learning but maintaining the licensing age for solo driving at 18 provided Swedish learners more opportunities to practice. In 2007 the Australian state of Queensland changed its GDL regulation to reduce the minimum age for obtaining the learner permit to 16 and required the permit be held for 12 months instead of 6 months, in addition to 100 hours of mandatory supervised driving. Scott-Parker et al. (2011) found most Queensland learners held their learner permit for a longer period. Using survey data, Gulliver et al. (2013) found that those new drivers who spent the most amount of time on their learner licence have reduced risk of on-road crash involvement as an unsupervised driver when compared to those who spend the least amount of time. Preusser and Tison (2007) concluded that the longer a learner's permit is required to be held delays the age at which a young person can obtain a licence and McCartt et al. (2010) found that this contributed to reducing young driver crashes.

2.4 Logbook completion requirement

While a mandated number of hours of supervised driving is common practice very few international jurisdictions require learners to record this practice using a logbook and present it to a licensing authority to confirm they have completed the required hours. However, this is required by learners in most jurisdictions in Australia. Bates (2012) studied the experiences of learner drivers in the Australian states of New South Wales and Queensland and concluded that the use of logbooks helped learners to structure their practice. Three quarters of this sample reported that the logbook entries were either accurate or very accurate. Although Bates, Watson and King (2014) document a paradox in that while most parents report their logbook entries were accurate, they thought the system was vulnerable to misuse and believed that others were not as diligent in the use of logbooks.

2.5 Passenger restrictions

The presence of passengers, particularly peer passengers is known to increase crash risk for teenage drivers (Rice, Peek-Asa and Kraus 2003). The more passengers that are present the greater the risk for younger drivers both at night and during the day (Williams 2007). Orsi et al. (2013) show that the presence of passengers is associated with the injury severity of young drivers. Chen et al. (2000) found that 16 to 17-year-old driver deaths per million trips were 1.99 without passengers, 2.76 with one, 3.69 with two and 5.61 with three or more.

There is also evidence to indicate that the gender of the passenger plays a role with the crash risk for teenage drivers increasing when the passengers are male teenagers whereas female teenage passengers do not have the same effects (see Williams, Ferguson and McCartt 2007, Bates et al. 2014b). Weiss, Kaplan and Prato (2014) report that a combination of male and female passengers dramatically increases the probability of serious and fatal injuries.

A reduction in crashes involving provisionally licensed drivers when there is a passenger restriction has been found using data from New Zealand (Begg and Stephenson 2003). McCartt et al. (2010) found that strong night-time and passenger restrictions are associated with a substantial reduction in young drivers' fatal crash rates. Walker, Thompson and Stevenson (2017) calculate that among young people aged 17-24 peer passenger restrictions could reduce hospitalisations annually by 14 in Queensland, 24 in New South Wales and by less than 1 death annually in each state.

2.6 Mobile/cell phone use

Using results from the US National Motor Vehicle Crash Causation Survey, Curry et al (2011) found that 19% of crashes involving teens could be attributed to distraction. Mobile/cell phone use is thought to add to distraction and to be a particular problem for inexperienced drivers. An established crash risk for both hand-held and hands-free cell phone use has been established for drivers in general (see e.g.Williams, 2007). Survey data indicates that those aged 18-24 are more likely to use a cell phone in a car (Glassbrenner 2005). Klauer et al. (2014) show that young drivers in their own vehicles have a higher crash risk while engaged in texting and driving. In a simulator study, Hosking, Young and Regan (2006) found that young inexperienced drivers spent up to 400% more time looking away from the road when texting than when not texting. In a small study of first-year psychology students aged 17-22 years, Gauld, Lewis and White (2014) found that 59% admitted to engaging in concealed texting even though most participants believed that concealed texting would result in police apprehension and being distracted from driving. Gauld et al. (2015) using a simulator study of young drivers aged 18-26 years found evidence that they reduced their speed when using a hands-held mobile phone in comparison to a hands-free mode. Nemme and White (2010) find that young drivers may engage in texting while driving even though they know it is unsafe to do so.

Williams (2017) report on research in the US that has shown that the introduction of a cell phone ban use by GDL drivers was not associated with crash reduction. McCartt, Kidd and Teoh (2014) also concluded that it was unclear that laws limiting drivers' cell phone use have the desired effects on safety. However, the method used to enforce these restrictions may be important in the effectiveness of this restriction (Foss et al. 2009).

2.7 New drive test

After California implemented a new driving performance evaluation road test that was longer, lasting about 25 minutes compared to the previous 10-15-minute test, Gebers, Romanowicz, and Hagge (1998) failed to find any reduction in crash involvement because of the implementation of this test. New Zealand and the Canadian provinces of British Columbia and Ontario introduced a second stage driver test that consists of an additional on-road test. However, there is no evidence that these tests reduce crash rates (Ferguson 2003).

Boufous et al. (2011) surveyed young drivers aged 17-24 years in the Australian state of New South Wales who had completed the on-road practical driving test required to be passed for learners to obtain a provisional phase 1 licence. They found that those who failed the test 4 times or more were at higher risk of being involved in a traffic crash compared to those who passed the test on the first attempt. Further, the crash risk among those who failed the practical on-road test at least 4 times was particularly high in females.

2.8 Alcohol

Alcohol-impairment increases relative crash risk for young drivers. Peck et al. (2008) found that the association between blood alcohol concentration (BAC) and crash risk is higher for young drivers under 21 than older drivers. In an examination of novice drivers in the Canadian province of British Columbia, Cooper, Pinili and Chen (1995) found that drink-driving was a factor proportionately more associated with crashes in the second and third year of driving than with the first. Using a meta-analysis covering jurisdictions in both Australia and the US, Zwerling and Jones (1999) found that restricted BAC laws for younger driver do appear to reduce crash risk.

2.9 Vehicle power restrictions

Vehicle power restrictions involve prohibiting new drivers from driving specified high-powered cars. There is limited evidence on the effectiveness of this restriction in reducing crash rates. Drummond (1994) consider that the impact on crashes would be minimal at best. Keall and Newstead (2013) note that benefits of high-powered vehicle restrictions in Australia will be modest due to the rarity of these vehicles. However, they did find a statistically significant higher crash and injury risk associated with these cars for young drivers compared to other cars. Although they also concluded that there was a considerable cost associated with implementing and enforcing these types of vehicle restrictions.

2.10 Gender differences

Amarasingha and Dissanayake (2014) find different factors are related to female and male drivers' injury risk. Cordellieri et al. (2016) investigated gender-related effects on road safety attitudes with drivers coming from nine different European countries. The results indicated that while the level of risk perception during driving is the same for males and females, they differ in the level of concern about the risk. Males appear to be less concerned about the risk of a road crash. Laapotti et al. (2001) compared crash and offence rates of 28,500 novice drivers in Finland. Young male drivers were found to be the drivers that took the greatest risks. The number of crashes and offences of novice drivers decreased with age and the decrease was larger among male drivers. Female drivers showed more problems with vehicle handling skills. Romano, Kelley-Baker and Voas (2008) found evidence that females in fatal crashes have increased over time. Chen et al. (2010) explored overall crash and injury trends for young drivers aged 17-25 residing in the Australian state of New South Wales (NSW) during 1997-2007. They found that while there has been a significant decline in young driver crashes in NSW regardless of injury severity, males' crash risk had reduced more than female young drivers. This suggests that policies and other contributing factors in NSW may have been more effective to influence young male drivers more than their female counterparts.

2.11 Summary

From the literature we conclude that there is evidence to indicate that revisions to the GDL that include: harsher sanctions for traffic offences, mandated hours supervised, increasing learners permit holding time, logbook completion, passenger restrictions and alcohol restriction policies may have some impact on reducing crash risk. However, changes that include restrictions to mobile phone use, vehicle power restrictions and the introduction of longer driving tests may not. Given there is evidence to suggest there are differences in driving behaviour between males and females and that the impacts of policy changes may affect their crash rates differently, the models we estimate are defined separately for males and females. In addition, we also test if the announcements of major policy changes have an impact on crash risk. Anticipatory responses to changes in GDL laws have been shown previously (*see, e.g.,* Cooper, Gillen and Atkins 2004).

3. Data

In this section we describe the data series used in this analysis. We have combined several series to create a composite data set. It was necessary to approximate the number of licensed drivers from a combination of sources. In addition, we have added calendar effects, indicator variables for the changes in the GDL system over the years from 2000 to 2007, indicator variables for official media announcements of the proposals, the proportion of new car sales, the average age of cars and the annual growth rate in youth unemployment. Table A.5 in the appendix provides the summary statistics for the series used.

3.1 Crash and driver data

The Traffic Accident Commission (TAC) online crash database (*http://www.tac.vic.gov.au/road-safety/statistics/online-crash-database*) is the source for the injury and fatality counts used within this paper. The TAC is a Victorian government-owned organization that provides a mandatory motor vehicle crash personal injury insurance under a no-fault scheme. Monthly data on fatalities and claims resulting in hospitalisation for drivers 18 to 25 and 40 to 59 by gender were obtained from the TAC online crash database for the period January 2000 to June 2017. The fatality data is compiled by the TAC from police reports supplied by Victoria Police. The data for claims resulting in hospitalisation is updated monthly from the TAC claims databases and is subject to a six-month reporting lag.

Data on the annual number of licensed drivers is generated from data obtained from several sources. We use the number of licensed drivers' data by single year of age for those aged from 18 to 24 given in Table A4 from Wundersitz, Bailey and Thompson (2017). For those aged 25, we use data on licensing rates in Table 4.2 from Bailey et al (2015) and Table A8 from Wundersitz, Bailey and Thompson (2017) and multiply these with the population data to obtain the number of licensed drivers for this age group. Licensing rates for drivers between the ages of 40 to 59 are also reported in these tables but since these are close to 100% we approximate these rates by using population data. Victorian population data by single year of age is available from the Australian Bureau of Statistics (ABS) report number

3101.0 entitled "Australian Demographic Statistics". The annual number of licensed drivers are interpolated to produce a monthly series using a cardinal spline algorithm (Lipow and Schoenberg 1973).[3]

By dividing the number of injuries requiring hospitalisation and fatalities found from the online TAC database by the number of licensed drivers, we construct injury and fatality rates per 100,000 licences between the ages of 18 to 25 and similarly for drivers between the ages of 40 to 59 by gender. The 40 to 59 age group rate is used to create a comparison group based on the research that has found these drivers to be the safest age group on Victorian roads (Buckis, Lenné and Fitzharris 2015).

3.1.1 Injury rates

To provide an overview of the number of driver injuries that result in hospitalisation for each of the constructed rates in Figure 1 we plot the underlying trend component by gender and age group[4]. As can be seen, there has been a substantial decrease in the rates for both 18 to 25 males and females. For females aged 18 to 25 a fall in the injury rates appears to occur prior to the period of major changes to the GDL system - between 2005 and 2006 whereas for males it appears to occur between 2006 and 2007. For males there also appears to be an increase in the rate during 2007 followed by another large decrease in 2008. By 2015 the rate for both young males and females have become similar although the rate for females appears to have been increasing from 2014. While both young male and female drivers still appear to have rates that are double those of the older drivers, there is little difference between the rates for older male and female drivers.

3.1.2 Fatality rates

In Figure 2 we plot the monthly underlying trend component for fatality rates per 100,000 licensed population for drivers aged from 18 to 25 as well as those aged from 40 to 59 by gender and age group. This figure highlights a fall in the rate of fatal crashes for the 18

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[3] The Cardinal Spline is based on the previous two non-missing values, and the next two non-missing values, and tries to fit the missing data to a non-linear, or curved, pattern. That is,

$$IV = \left(2\lambda^3 - 3\lambda^2 + 1\right)P_{i-1} + \left(1-t\right)\left(\lambda^3 - 2\lambda^2 + \lambda\right)\left(P_{i+1} - P_{i-2}\right) - \left(2\lambda^3 - 3\lambda^2\right)P_{i+1} + \left(1-t\right)\left(\lambda^3 - \lambda^2\right)\left(P_{i+2} - P_{i-1}\right)$$

where P_{i-2} and P_{i-1} are the previous two non-missing values, P_{i+2} and P_{i+1} are the next two non-missing values, t affects the curvature of the spline and is equal to 0.1 here and λ is the relative position of the missing value divided by the total number of missing values in a row.

[4] The monthly underlying trend is obtained by removing the cyclical seasonal movement. The US Census Bureau X-13 seasonally adjustment tool available in *Eviews* 10 is used to do this. Annual totals of the adjusted series match those of the original series.

to 25-year-old males. Over the sample period, fatality rates for this group have typically been much higher than for the corresponding 18 to 25-year-old females which appear to have similar fatality rates to the 40 to 59-year-old subgroups.

Figure 1: Underlying trend component of monthly rate of driver injuries that result in hospitalisation by age and gender per 100,000 licences, Victoria with notations for the 6 GDL changes.

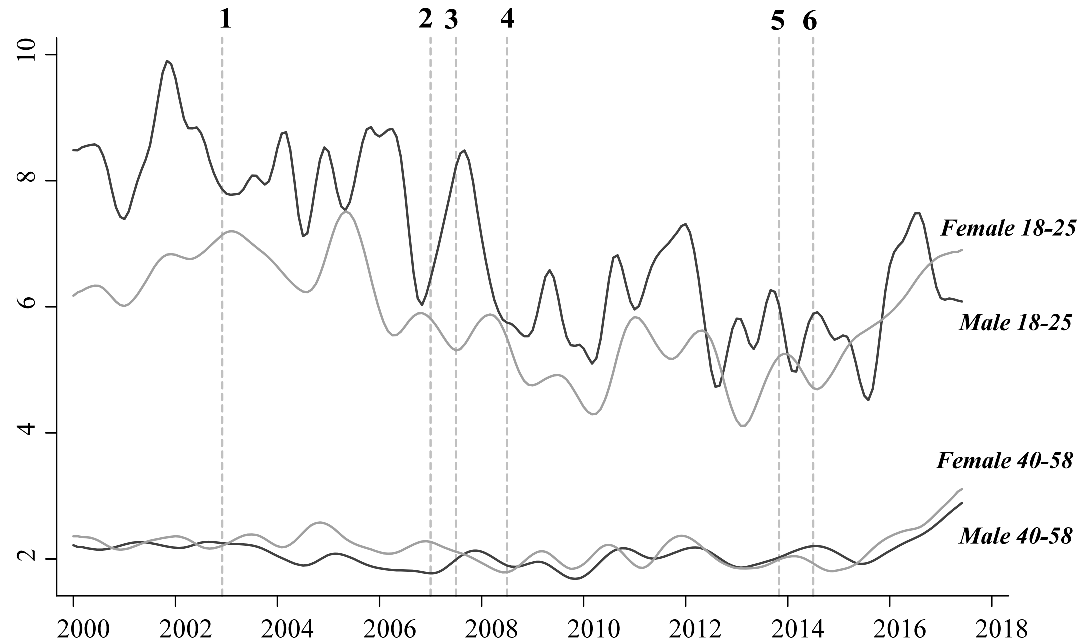
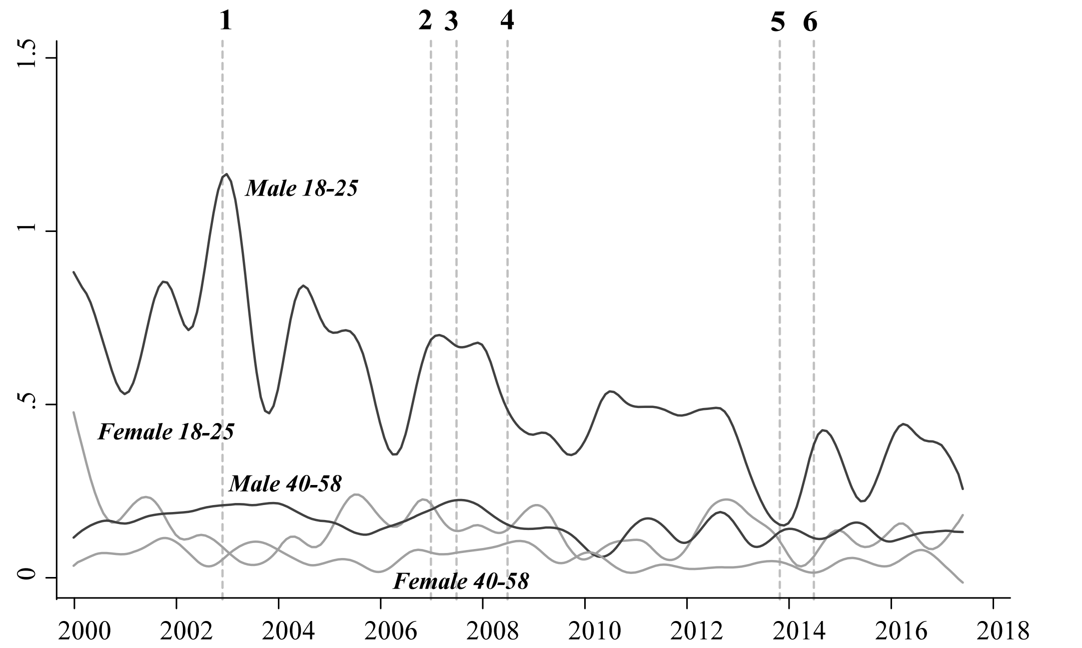


Figure 2: Underlying trend component of monthly driver fatality rates by age and gender per 100,000 licences, Victoria with notations for the 6 GDL changes.



3.2 Additional factors that influence injuries and fatalities

In the modelling of injuries and fatalities we account for the seasonality in the monthly data by the inclusion of monthly indicator variables. We also include the proportion of new cars among total vehicle registrations and the average age of vehicles in Victoria to account for safety improvements[5]. Recessions are linked to high youth unemployment and a decline in youth licensing (Delbosc and Currie 2013). We include the annual growth rate in youth unemployment to account for any impacts of the Global Financial Crisis that occurred between mid-2007 and early 2009. The proportion of a month that is made up of Fridays, Saturdays and Sundays is also included to provide an indicator of the proportion of each month made up of weekends to account for calendar effects. These variables are defined as:

pcars = sale of new cars in the Australian State of Victoria (passenger vehicles and sports utility vehicles) from ABS report number 9314.0 divided by passenger vehicles on register from ABS report number 9309.0.
avg_age = estimated average age of motor vehicles in Victoria from ABS report number 9309.0
gunemp = annual growth rate in youth unemployment in Victoria from ABS report number 6202.0
pends = this is defined as $\sum(\text{Fridays+Saturdays+Sundays}) / \text{total days in month}$.

For each of the policy changes we construct a dummy variable to account for the modifications to the GDL. These are defined as:

1. *Dec2002* = 0 before December 2002 and 1 after;
2. *Jan2007* = 0 before January 2007 and 1 after;
3. *July2007*= 0 before July 2007 and 1 after;
4. *July2008* = 0 before July 2008 and 1 after;
5. *Nov2013* = 0 before November 2013 and 1 after;
6. *Jul2014* = 0 before July 2014 and 1 after;

Dummy variables are also included for the announcements in the media of the 2007 proposed changes to the GDL system to capture possible anticipatory responses[6].

Aug2005 (Gardiner 2005)

Jun2006 (Houlihan and Freegard 2006).

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[5] These were both annual series that were interpolated to produce a monthly series using a cardinal spline algorithm.

[6] These dates were identified by searching local newspapers to identify the first mention of the proposed rules.

4. Model Specification

We estimate two model specifications. In the first, we include the *current* dummy variable that is defined as equal to one for all months after the date on which the change in GDL goes into effect and zero prior to that date. However, to account for the possible diminishment of the impact over time, we also estimate a model that includes lags on each policy change dummy to allow for the effect of the policy changes in our data to vary over time.[7]

4.1 Model Specifications

We assume the number of serious traffic related incidents for drivers aged 18 to 25 $(N_{1825})_t$ is Poisson distributed with mean μ_t and is defined as either the number of claims resulting in hospitalisation for drivers (injuries) or the number of fatalities (fatalities).

Model 1

Model 1 is specified with only the *current* dummy variables included as explanatory variables to account for each policy change. The specification of μ_t is defined by (1).

$$\mu_t = \exp\begin{pmatrix} \beta_0 + \boldsymbol{\gamma}'\mathbf{X}_t + \delta M_t + \eta_0 dec\_2002_t + \lambda_0 jan\_2007_t \\ + \mu_0 jul\_2008_t + \pi_0 nov\_2013_t + \varphi_0 jul\_2014_t \end{pmatrix} \quad (1)$$

where $\boldsymbol{\gamma}$ is the vector of parameters and $\mathbf{X}_t$ is a vector of explanatory variables for observation *t*. These variables include: the proportion of new cars (*pcars*), the average age of cars (*avg_age*), annual growth rate in youth unemployment (*gunemp*), the proportion of the month that is Fridays, Saturdays and Sundays (*pends*), two dummy variables for the announcements of the proposed changes of the GDL system and the incident rates for fatalities or injuries for all 40 to 59-year-old drivers in Victoria is given by R_{4059t} for the same month. We include R_{4059t} to represent an "untreated" group of drivers that are not directly affected by changes to the GDL system over this period and is included to account for the general road safety during the period.[8] We use the combined rate for both male and female

[7] For example, a 3 stage GDL system was introduced in New Zealand in August 1987. Following the introduction there was an immediate sharp reduction in driving by young people reducing their exposure to crash risk as well as an initial decline in driver licence numbers however, within a few years this had recovered to a level similar to before the GDL system (Begg 2003).

[8] We assume that the crash rates for these drivers are not influenced by the actions of the 18 to 25-year-old drivers and that technological factors that influence the safety of older drivers are equally shared by all drivers.

drivers since there is no discernible gender differences in these rates. *M* is a set of monthly dummy variables to account for seasonality in crash rates.

Model 2

The specification of μ_t has the same variables as in Model 1 but in addition up to five lagged dummy variables are included as explanatory variables for each policy change to allow for a lagged response as well as an instantaneous response.

$$\mu_t = \exp\begin{pmatrix} \beta_0 + \gamma'\mathbf{X}_t + \delta M_t + \eta dec\_2002_t + \sum_{j=1}^{5} \eta_j dec\_2002_{t-j} + \lambda jan\_2007_t \\ + \sum_{j=1}^{5} \lambda_j jan\_2007_{t-j} + \mu jul\_2008_t + \sum_{j=1}^{5} \mu_j jul\_2008_{t-j} + \pi nov\_2013_t \\ + \sum_{j=1}^{5} \pi_j nov\_2013_{t-j} + \varphi jul\_2014_t + \sum_{j=1}^{5} \varphi_j jul\_2014_{t-j} \end{pmatrix} \quad (2)$$

Our preferred specification is chosen by selecting the highest significant lag for each policy change.

Models 1 and 2 are estimated in *Stata* using the *glm* (generalised linear models) program. The distribution of the dependent variable $(N_{1825})_t$ in both cases is assumed to be Poisson. The exposure variable is the per 100,000 licensed population of 18 to 25-year-olds in Victoria. Each model is estimated separately for males and females. We combine the results for males and females using the *suest* post-estimation routine in *Stata* (see Weesie 1999). The standard errors are clustered by year to allow for cross-equation correlations in order to test for gender differences in the results. To interpret the estimated parameters on the policy and announcement dummy variables we use the formula to determine the percentage change from a dummy variable when estimating a log-linear model as the case with a Poisson model defined as: $100[\exp(\widehat{coeff})] - 1\%$. For Model 1 $\widehat{coeff}$ corresponds to the estimated coefficient on the policy dummy variable whereas for Model 2 it is the sum of the estimated coefficient on the policy dummy variable and the lags of the policy dummy variable. Where in both Models 1 and 2 $\widehat{coeff}$ corresponds to the estimated coefficient on the announcement dummy variable. The % is then multiplied by the average number of injuries resulting in hospitalisation or fatalities over the period of our data to estimate the impact on monthly injuries resulting in hospitalisation or fatalities.

5. Results

Our results indicate that there has been an impact of the GDL on both injuries resulting in hospitalisation and fatalities. However, not all the modifications to the GDL have had a measurable impact, nor has this impact been uniform for both male and female drivers. In this section we provide the results of the two specifications for both male and female injuries that resulted in hospitalisation and in fatalities.

5.1 Injuries that resulted in hospitalisation.

The complete set of estimated parameters by gender for models 1 and 2 are reported in Tables A.1 and A.2 respectively. Both models are applied to the hospitalisation rates for 18 to 25-year-old drivers due to injuries. The total impacts of the GDL policy changes and the associated preliminary announcements of these changes are summarized in Tables 2 and 3 for Models 1 and 2 respectively. Although the results are similar for both specifications the specification in Model 1 is found to result in the highest adjusted R^2.[9]

In Table 2 the December 2002 policy change on male drivers indicates a significant estimated reduction of around 2 injuries per month. While, this result does not appear to be mirrored in young females we cannot reject the hypothesis that the impact is significantly different between males and females. Interestingly, we find that the announcements of the major changes occurring to the GDL system in 2007 and 2008 had significantly different impacts on injuries for males and females. Females appear to have responded to the earlier announcement and the males to the latter one. We find that both result in an estimated reduction of around 7 injuries per month. Also, we find that the July 2008 dummy variable is also significant and negative for both males and females and we cannot reject that the impact is significantly different between males and females. These results can be interpreted as an estimated reduction of around 4-5 injuries per month. For males, there appears to be a significant positive impact on injuries with the January 2007 policy change resulting in an increase of around 5 injuries per month. The media announcement prior to the introduction of the July 2008 policy change that required a mandatory 120 hours of supervised driving for learner drivers, was reported to have generated a rush of applications by probationary drivers

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[9] This comparison is based on the estimation of Model 1 with the same number of observations as used in the estimation of Model 2. In this case we obtained an adjusted R^2 of .365 for males and .259 for females.

(Lucas 2008). However, we do not find evidence of a significant corresponding impact of this announcement for females.

Table 2: Impacts of policy changes and announcements on injuries using Model 1

	Males		Females		
	%Change	**Est. Number**	**%Change**	**Est. Number**	**Sig. difference**
Policy Changes					
Dec 2002	**-7.58****	**-2.35**	-6.28	-1.61	-1.30
Jan 2007	**15.25*****	**4.73**	-3.66	-0.94	**18.92*****
Jul 2007	-0.79	-0.25	7.64	1.96	-8.43
Jul 2008	**-17.29*****	**-5.36**	**-16.06*****	**-4.13**	-1.22
Nov 2013	-6.33	-1.96	3.42	0.88	-9.74
Jul 2014	0.61	0.19	-1.00	-0.26	1.60
Announcements					
Aug 2005	4.73	1.47	**-25.29*****	**-6.50**	**30.02*****
Jun 2006	**-23.13*****	**-7.18**	4.83	1.24	**-27.96****
$\chi^2_{df=8}$ *composite test*	**318.09*****		**110.19*****		

*** p < .01, ** p < .05, * p < .1. The significance levels are based on the application of the delta approximation for the standard error. $\%\text{change}=100\left[\exp\left(\widehat{coeff}\right)-1\right]\%$; Est. Number=%change $\times$ average monthly injuries. Sig difference tests whether %change is significantly different between males and females.

The estimated parameters for Model 2 are listed in Table A.2 in the Appendix. In these models we have included the lagged indicator variables to account for the possibility that the impacts of the GDL changes occurred after the date on which they were instituted. To determine the appropriate number of lags we chose the model with the number of lags that resulted in the highest quality fit as measured by the adjusted R-squared. The various lag lengths are provided in Table A.2. The results reported in Table 3 are very similar to those in Table 2 although with these results we do not find a significant impact for the December 2002 policy change for either males or females.

The other variables in both models fit to the injury data vary in significance. The rate of injuries for the older drivers (*acc4059*) is positive and significant in Models 1 and 2 for both males and females. In both models we detect that the proportion of new car sales to total number of registered cars (*pcar*) is negative and significant for males. But, only in Model 1 do we observe that the proportion of new car sales has a influence for females. The average age of cars on the road (*avg_age*) appears to have had no impact on the injury rate from either model for either gender. The growth rate in the youth unemployment rate (*gunemp*) is negative and significant for females in Model 1 only. The proportion of the months that are Friday, Saturday and Sundays (*pends*) is negative and significant in both models for females. This is the only case where we find a marginally significant difference in the estimated coefficients between males and females[10]. The negative value indicates that female drivers were less likely to have a crash on a weekend and this may be due to driving less during the weekends. In all models fit to the injury data we were able to reject the null hypothesis of no seasonal influence (that all the monthly dummies are equal to zero). Also note that the test of the hypothesis that all policy changes and announcement dummies were zero was also rejected for all four cases as shown by the Chi-square test that they are all equal to zero as reported in the last line of Tables 1 and 2.

Table 3: Cumulative impacts of policy changes and announcements on injuries using Model 2

	Males		**Females**		**Sig. difference**
	%Change	**Est Number**	**%Change**	**Est Number**	
Policy Changes					
Dec 2002	-6.05	-1.88	-8.54	-2.19	2.49
Jan 2007	**12.94*** **	**4.01**	-4.19	-1.08	**17.13*** **
Jul 2007	0.77	0.24	8.11	2.08	-7.34
Jul 2008	**-16.62*** **	**-5.15**	**-16.38*** **	**-4.21**	-0.24
Nov 2013	-5.48	-1.70	9.29	2.39	**-14.77***
Jul 2014	2.68	0.83	-6.65	-1.71	9.34
Announcements					
Aug 2005	**5.82***	**1.81**	**-24.84*** **	**-6.38**	**30.66*** **
Jun 2006	**-22.87*** **	**-7.09**	5.17	1.33	**-28.04** **
$\chi^2_{df=8}$ *composite test*	**338.02*** **		**96.75*** **		

*** p < .01, ** p < .05, * p < .1. The significance levels are based on the application of the delta approximation for the standard error. %change= $100\left[\exp\left(\widehat{coeff}\right)-1\right]\%$; Est. Number=%change $\times$ monthly mean injuries. Sig difference tests whether %change is significantly different between males and females.

5.2 Fatalities

Our estimation of the impact on the fatality rates is done in an analogous fashion to the analysis of the injury rates by fitting the same models. From Figure 3, the rate of fatalities for young male drivers drops by almost 50% from 2000 to 2017. While during the same period, the rate for female drivers of the same age and for older drivers display almost no secular

[10] The test of differences between the coefficients of *pends* has a *p*-value of .10 for Model 1 and .06 for Model 2.

trends in fatality rates. The estimation results by gender are reported in Tables A.3 and A.4 for Models 1 and 2 respectively. The impacts of the policy changes and the associated announcements are reported in Tables 4 and 5 listed below. Note that although the results are similar for both model specifications, Model 2 is preferred based on the adjusted R^2.[11]

From Table 4 we can note that for young males, the August 2005 announcement of the major changes occurring to the GDL system is significant and resulted in an estimated reduction of around 0.6 fatality per month. The July 2008 policy change is significant for males and resulted in an estimated reduction of around 0.8 fatality per month. The total ban on mobile phones (including hands-free) in November of 2013 resulted in an additional 1.3 drop in fatalities for males. However, policy changes in both January 2007 and July 2014 appear to be associated with a significant positive increase in fatalities for males of 0.8 and 2.3 fatalities per month respectively. The increase in January 2007 may be due to the rush of applications for probationary drivers prior to the introduction of the July 2008 policy change. The July 2014 policy change was associated with the loosening of the power restriction on P-plate drivers. For females the January 2007 policy change was negative resulting in an estimated reduction of around 0.2 fatalities per month around and significant and positive for the July 2007 policy change resulting in an estimated increase of approximately 0.3 fatalities per month. We only found significant differences in percentage changes between males and females for the January 2007 and July 2007 policy changes. This may be due to female monthly fatality rates being consistently small and tracking much more like the rates for the older drivers as illustrated in Figure 2.

Table 5 lists the impacts of the GDL changes based on the estimates from the application of Model 2 to the fatality data. Again, the number of lags included vary depending on the fit of the models. The results for Model 2 are very similar to those for Model 1. However, the January 2007 policy change is no longer significant for males and July 2007 is no longer significant for females. In addition, the total ban on mobile phones in November of 2013 is now negatively significant for females resulting in a reduction of 0.5 fatalities and the %change for females is not significantly different from the %change for males.

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[11] This comparison is based on the estimation of Model 1 with the same number of observations as used in the estimation of Model 2. In this case we obtained an adjusted R^2 of .147 for males and .036 for females.

Only for females are some of the other variables significant. *Pends* is the only variable that is significant for females in both models although it is only significantly different between males and females in Model 1. It is positive which suggests that if females are driving on the weekends there is a higher likelihood of them having a fatal crash. The composite Chi-square test that all the policy changes had no influence can be rejected at less than the .001 level of significance for both males and females in both models. We were able to reject the null hypothesis of no seasonal influence in both models fit to the fatality data .

Table 4: Impacts of Policy Changes and Announcements Fatalities– Model 1

	Males		**Females**		
	%Change	**Est. Number**	**%Change**	**Est. Number**	**Sig. difference**
Policy Changes					
Dec 2002	-15.75	-0.39	-28.95	-0.21	13.20
Jan 2007	**30.74****	**0.76**	**-25.07*****	**-0.18**	**55.82*****
Jul 2007	-12.50	-0.31	**36.84*****	**0.27**	**-49.34*****
Jul 2008	**-30.63*****	**-0.76**	-10.96	-0.08	-19.67
Nov 2013	**-54.16*****	**-1.34**	-57.97	-0.42	3.81
Jul 2014	**92.62***	**2.30**	151.36	1.09	-58.74
Announcements					
Aug 2005	**-26.78****	**-0.66**	33.04	0.24	-59.82
Jun 2006	10.83	0.27	-9.77	-0.07	20.61
$\chi^2_{df=8}$ *composite test*	**104.00*****		**21.33*****		

*** p < .01, ** p < .05, * p < .1. %change=$100\left[\exp\left(\widehat{coeff}\right)-1\right]\%$; Est. Number=%change$\times$ monthly mean injuries. Sig difference tests whether %change is significantly different between males and females.

5.3 Robustness

To establish if the results we report are subject to assumptions made in the modelling we attempted to replicate these results with a series of alternative specifications for the distributional assumption for the estimation of Models 1 and 2. Our reported results varied little from regressions reported above when we use standard OLS or least absolute deviation models with the log of the rates as the dependent variable. Furthermore, these results were not influenced by various assumptions for the estimation of the covariance matrix of the coefficients. In addition, we found that alternative definitions for the number of new cars, the weekend versus holidays, or the use of the total of the injuries or fatalities of the older driver group versus the fatalities and injuries by gender, had almost no influence on our results. As an additional check we also estimated these models using alternative routines in *Stata* and SAS. These estimates provided the same or equivalent results.

Table 5: Impacts of Policy Changes and Announcements Fatalities– Model 2

	Males		Females		Sig. difference
	%Change	Est. Number	%Change	Est. Number	
Policy Changes					
Dec 2002	-9.38	-0.23	-42.03	-0.30	32.65
Jan 2007	18.69	0.46	**-24.62****	**-0.18**	**43.31****
Jul 2007	3.61	0.09	18.94	0.14	-15.33
Jul 2008	**-33.67*****	**-0.84**	-2.19	-0.02	-31.48
Nov 2013	**-48.35*****	**-1.20**	**-68.69****	**-0.49**	20.34
Jul 2014	**102.49***	**2.54**	115.23	0.83	-12.74
Announcements					
Aug 2005	**-23.86***	**-0.59**	17.04	0.12	-40.90
Jun 2006	9.02	0.22	-12.07	-0.09	21.09
$\chi^2_{df=8}$ composite test	**59.70*****		**39.22*****		

*** p < .01, ** p < .05, * p < .1. %change=$100\left[\exp\left(\widehat{coeff}\right)-1\right]\%$; Est. number=%change$\times$ mean injuries per month. Sig difference tests whether %change is significantly different between males and females.

6. Discussion

Prior to changes in the GDL system regulations there was a decline in young adult driver licence holders in Victoria that may have resulted in lower injury and fatality rates. Licence-holding fell over 1% per year for people up to age 30 from 2001 to 2011. One explanation for this is the changing lifestyle of young people. Delbosc and Currie (2014a) for example, found that part-time work and studying are associated with lower licensing rates. In Australia, the percent of 20-24-year-olds attending some form of tertiary education has been increasing from 25% in 1991 to 41% in 2011.

However, changes to the GDL system regulations have had both an indirect and direct effect on reducing crash rates. The indirect effect arises because the licensing restrictions, such as 120 hours of supervised driving for learner drivers, acts as a short-term barrier (Delbosc and Currie 2014b). Thus, young people may delay the age at which they obtain a licence and the older novice drivers tend to have a lower risk of crash involvement (Preusser and Tison 2007, Cooper, Pinili and Chen 1995). By 2014 there were nearly three times more 24-year-old new licence holders in Victoria than in 2002 (Bailey et al. 2015).

The results of our model estimation highlight direct effects of the GDL system regulations on crash rates. Speeding has consistently been found to be a factor that influences crash rates for males (Laapotti and Keskinen 2004). Although, our results indicate that the demerit point system introduced for traffic violations in December 2002 only had a short-term impact of reducing injuries requiring hospitalisation of around 2 per month for males.

We do observe that the signalling of the GDL system changes resulted in around 6 less injuries requiring hospitalisation per month for females and around 7 less injuries requiring hospitalisation for males per month. For fatalities, these signals only had an impact for males of around 0.6 fewer fatalities per month. Proposed changes to the GDL system had been announced in the media in August 2005 (Gardiner 2005) and again in June 2006 (Houlihan and Freegard 2006). Results from the Victorian Learner Monitor survey saw an increase in hours of supervised driving over this period although only males in metropolitan Melbourne appeared to be averaging 120 hours (Meyer et al 2015).

The modifications introduced in July 2008 resulted in fewer injuries per month requiring hospitalisation. We found approximately 5 fewer injuries for males and around 4 less injuries for females. This change also resulted in around 0.8 less fatalities per month for males. The major changes to the GDL system for this period included an extra year on "P plates" for those under 21 at time of licensing and to remain alcohol free while driving for the entire probationary period with peer passenger restrictions introduced for first year P platers as well. Previous results in the literature have found that these factors are also associated with lower crash rates. In particular, with reference to BAC levels Keall, Frith and Patterson (2004) for example, found that drivers in their twenties are estimated to have three times the crash risk of drivers aged over 30. There is also much evidence to indicate that the presence of teen passengers increases the risk of crash injury (e.g. Lam 2003, Weiss, Kaplan and Prato 2014 and McCartt and Teoh 2015).

The stricter mobile phone restrictions introduced for P platers in November 2013 resulted in around 1 less fatality per month for males and around half that effect for females. However, this change had no impact on injuries requiring hospitalisation for either males or females. In Victoria in 2017, a TAC survey found that nearly half of all drivers aged under 25 ignored the ban and still used their phone while driving (Rooney and Hore 2018). Truelove, Freeman and Davey (2019) find in a study of GDL compliance in Queensland that the mobile phone restriction was the least complied with GDL restriction. Williams (2007) concludes that the contribution of bans on mobile phone use are likely to be slight and McCartt, Kidd and Teoh (2014) note that it may not have the desired effects on safety.

Interestingly, for males we found a significant increase of around 4 injuries requiring hospitalisation per month associated with the January 2007 policy change. The January 2007 policy change involved only minor modifications to the requirement of carrying a licence and the introduction of alcohol interlock measures for probationary drivers under the age of 26 found to be guilty of a BAC over the limit. However, the significant increase in injuries requiring hospitalisation for males found after this policy change may have been due to greater numbers of inexperienced learner drivers rushing to obtain their probationary licence prior to the introduction in July 2007 of the mandatory requirement of 120 hours of supervised driving experience (eg see Lucas 2008). Short-term distortions arising as a result of individual's behaviour leading up to the anticipated introduction of a government policy have been shown previously (eg Gans and Leigh 2009).

Our results also highlight gender differences in response of changes to GDL rules. We show that females may tend to respond earlier to announcements about upcoming changes than males. The introduction of 120 hours of supervised driving may have led to an increase in crashes for males. However, we do not find that the impact of the July 2008 policy changes was different between males and females.

There are several limitations to the current study. The current analysis only examined traffic crashes that resulted in a fatality or a serious injury defined as resulting in hospital admissions. Thus, not all crashes were examined. Monthly data was not available for several variables including licensing rates, new car sales, number of registered passenger vehicles and average age of registered cars. Monthly data for these variables needed to be approximated using interpolation methods. Aggregate data on traffic crashes of drivers aged 18-25 was used but we were unable to distinguish between the two classes of provisional licence holders.[12] Hence, we were unable to measure the different impacts on crashes modifications to the GDL had on these two groups. GDL restrictions are different in each Australian state and territory and changes to GDL rules have also occurred at different times. This study only used data from Victoria.

7. Conclusions

The findings of the present study indicate that some of the modifications to the GDL system have contributed to reductions in fatality and hospitalisation rates. The policy changes in July 2008 that included requiring novice drivers under 21 to spend an additional year on their P-plates as well as continuing to remain alcohol free for this additional period and the introduction of passenger restrictions for new P-plate drivers resulted in significant

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[12] This distinction was introduced in 20XX.

falls in crashes resulting in hospitalisation of both males and females and crashes resulting in male fatalities. Truelove, Freeman and Davey (2019) found in a study of GDL compliance in Queensland that young drivers knew about the passenger restriction and that the zero-alcohol limit was the most complied with GDL restriction. P-plate drivers are required to display plates on their vehicles that indicates licence stage. This may help to enforce these types of restrictions (Bates 2014b). Parents may also play an active role in supporting these aims (Bates, Filtness and Watson, 2018).

Our evidence demonstrates that official announcements of future modifications have an impact on driving behaviour. There was a reduction in crashes resulting in hospitalisation for males and females although females appear to respond earlier to changes than males. There was a reduction in fatalities for males. Authorities should be aware of the timing of announcements and of the impacts that can result from signalling proposed changes.

However, authorities also need to be aware of introducing significant changes all at once. We found the introduction of the mandatory 120 hours may have rushed male learners to gain their licence. This would imply that a staggered introduction of significant changes might be a more effective strategy for the introduction of such measures.

Our findings showed that the introduction of the mobile phone ban in November 2013 had no impact on crashes resulting in hospitalisation of either males or females although there was a reduction in fatalities for both males and females. Media are reporting that nearly half of all drivers aged under 25 still used their phone illegally (Rooney and Hore 2018). Truelove, Freeman and Davey (2019) conclude that the mobile phone restriction was the least complied with GDL restriction. In Figure 1 it appears that crash rates involving hospitalisation have been increasing from 2014 for females. Mobile phone use is thought to add to distraction and young drivers engaged in texting and driving have a higher crash risk (Klauer et al 2014). The compliance and enforcement of mobile phone restrictions is worthy of further investigation.

Our results focus on differences to the modifications to the GDL system by gender. However, the level of urbanization has been shown to be a factor that impacts crash rates (Bates et al 2014b). Future research could examine differences in the impact of the revisions to the GDL by the locality and road condition.

Acknowledgements

The authors would like to thank the referees and editor of this journal for their insightful and useful comments on this paper.

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Appendix

Table A.1: Estimation results for injuries – Model 1

VARIABLES	***Males***	***Females***
Policy Changes		
Dec 2002	-0.079**	-0.065
Jan 2007	0.142***	-0.037
Jul 2007	-0.008	0.074*
Jul 2008	-0.190***	-0.175***
Nov 2013	-0.065	0.034
Jul 2014	0.006	-0.010
Announcements		
Aug 2005	0.046	-0.292***
Jun 2006	-0.263***	0.047
Other Variables		
Acc4059	0.083***	0.056**
Pcar	-0.713***	-0.591*
Avg_age	-0.085	-0.428
Gunemp	-0.001	-0.002*
Pends	-0.005	-0.014***
Feb	0.181***	0.098
March	0.044	0.090*
April	-0.008	-0.009
May	0.004	0.006
June	0.024	0.103
July	0.094	0.089
August	0.046	0.128***
Sept	0.040	-0.072
Oct	0.011	-0.048
Nov	0.069	0.050
Dec	0.023	-0.063
Constant	-8.235***	-4.488
Adj-R^2	.370	.263
χ^2- test seasonality	118.92***	50.93***
Observations	210	210

*** p < .01, ** p < .05, * p < .1. D.V. = the number of claims involving hospitalisation for drivers 18 to 25. family = Poisson. exposure = 18 to 25 100,000 licensed population in Victoria. *P*-values are based on the joint estimation of the covariance matrix of males and females using cluster-robust standard errors adjusting for clustering by year.

Table A.2: Estimation results for injuries – Model 2

VARIABLES	Males	Females
Policy Changes		
Dec 2002$_t$	0.093*	-0.018
Jan_2003$_t$	-0.220***	0.162*
Feb 2003$_t$	0.180***	-0.233***
Mar 2003$_t$	-0.337***	
Apr 2003$_t$	0.222***	
Jan 2007$_t$	0.247***	-0.043
Feb 2008$_t$	-0.125*	
Jul_2007$_t$	0.008	0.078*
Jul 2008$_t$	-0.382***	-0.248***
Aug 2008$_t$	0.156*	0.235*
Sep 2008$_t$	-0.230***	-0.202*
Oct 2008$_t$	0.442***	0.037
Nov 2008$_t$	-0.168***	
Nov 2013$_t$	-0.056	0.339***
Dec 2013$_t$		-0.375***
Jan 2014$_t$		-0.269***
Feb 2014$_t$		0.441***
Mar 2014$_t$		-0.375***
Apr 2014$_t$		0.327***
Jul 2014$_t$	-0.012	-0.043
Aug 2014$_t$	-0.496***	
Sep 2014$_t$	0.534***	
Announcements		
Aug 2005	0.057*	-0.286***
Jun 2006	-0.260***	0.050
Other Variables		
Acc4059	0.080***	0.055***
Pcar	-0.654***	-0.638
Avg_age	-0.016	-0.448
Gunemp	-0.001	-0.002
Pends	-0.005	-0.015***
Feb	0.184***	0.066
March	0.037	0.097
April	0.020	-0.024
May	0.014	-0.009
June	0.014	0.083
July	0.106	0.080
August	0.070	0.103*
Sept	0.056	-0.084
Oct	0.005	-0.062
Nov	0.070	0.016
Dec	0.024	-0.073
Constant	-9.022***	-4.155
Adj-R^2	.356	.252
χ^2- test seasonality	61.38***	39.26***
Observations	204	204

*** p < .01, ** p < .05, * p < .1. D.V. = the number of claims involving hospitalisation for drivers 18 to 25. family = Poisson. exposure = 18 to 25 100,000 licensed population in Victoria. *P*-values are based on the joint estimation of the covariance matrix of males and females using cluster-robust standard errors adjusting for clustering by year.

Table A.3: Estimation results for Fatalities – Model 1

VARIABLES	Males	Females
Policy Changes		
Dec 2002	-0.171	-0.342
Jan 2007	0.268**	-0.289**
Jul_2007	-0.134	0.314***
Jul 2008	-0.366**	-0.116
Nov 2013	-0.780***	-0.867
Jul_2014	0.656**	0.922
Announcements		
Aug_2005	-0.312*	0.285
Jun 2006	0.103	-0.103
Other Variables		
Fat4059	0.241	1.011
Pcar	1.159	-3.579***
Avg_age	0.058	0.173
Gunemp	0.001	-0.002
Pends	0.008	0.056***
Feb	-0.241	-0.679*
March	0.245	-0.499
April	-0.218	-0.578*
May	0.307	-0.158
June	0.016	-0.043
July	-0.023	0.263
August	-0.170	-0.154
Sept	-0.161	-0.793
Oct	0.051	-0.095
Nov	0.009	0.170
Dec	0.285*	-0.262
Constant	-13.363*	-15.257
Adj-R^2	.173	.084
χ^2- test seasonality	50.05***	54.64***
Observations	210	210

*** p<0.01, ** p<0.05, * p<0.1. . D.V. = the number of fatalities for drivers 18 to 25. family = Poisson. exposure = 18 to 25 licensed 100,000 population in Victoria. *P*-values are based on the joint estimation of the covariance matrix of males and females using cluster-robust standard errors adjusting for clustering by year.

Table A.4: Estimation results for Fatalities – Model 2

VARIABLES	Males	Females
Policy Changes		
Dec 2002$_t$	-0.099	-0.545
Jan 2007$_t$	0.795***	-0.283**
Feb 2007$_{t-1}$	-0.711***	
Mar 2007$_{t-2}$	0.087	
Jul_2007$_t$	0.035	0.173
Jul_2008$_t$	0.394**	0.073
Aug_2008$_{t-1}$	-0.805***	
Nov 2013$_t$	-0.661***	-1.161
Jul_20014$_t$	0.706***	0.767
Announcements		
Aug 2005	-0.273	0.157
June 2006	0.086	-0.129
Other Variables		
Fat4059	0.058	1.614**
Pcar	0.161	-1.760
Avg_age	0.507	-1.165
Gunemp	-0.001	0.001
Pends	0.012	0.054***
Feb	-0.248	-0.803*
March	0.283	-0.411
April	-0.249	-0.471
May	0.318	0.036
June	0.098	-0.028
July	-0.055	0.359
August	-0.157	-0.082
Sept	-0.166	-0.673*
Oct	0.055	0.023
Nov	0.008	0.297
Dec	0.307*	-0.218
Constant	-17.604***	-2.527
Adj-R^2	.160	.036
χ^2- test seasonality	56.40***	33.51***
Observations	204	204

*** p<0.01, ** p<0.05, * p<0.1. D.V. = the number of fatalities for drivers 18 to 25. family = Poisson. exposure = 18 to 25 100,000 population in Victoria. *P*-values are based on the joint estimation of the covariance matrix of males and females using cluster-robust standard errors adjusting for clustering by year.

Table A. 5 Summary statistics for monthly variables used in estimation.

nmemonic	*Label*	*Mean*	*Std Dev*	*Min*	*Max*
acc4059	All 40 to 59 injury rate (per 100,000)	4.25	0.77	2.49	6.64
afem	Female18 to 25 Number of injuries	25.70	6.44	10.00	44.00
amale	Male 18 to 25 Number of injuries	31.02	7.11	14.00	54.00
avg_age	estimated average age of motor vehicles	10.13	0.25	9.69	10.70
fat4059	All 40 to 59 fatality rate (per100,000)	0.22	0.12	0.00	0.63
gunemp	annual growth rate in youth unemployment	-0.10	10.39	-23.36	43.14
nf	Female 18 to 25 Fatalities	0.72	0.83	0.00	4.00
nm	Male 18 to 25 Fatalities	2.48	1.71	0.00	7.00
pcar	Proportion of new cars to registered cars	0.58	0.04	0.41	0.83
pends	% days in month that are Fri, Sat and Sun	42.86	3.03	38.71	48.39
slpop1825	18 to 25 licence holders (1,000s)	441.73	15.07	410.37	465.63