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Deadlier road Accidents? Traffic safety regulations and heterogeneous motorists' behavior

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Deadlier Road Accidents? Traffic Safety Regulations and Heterogeneous Motorists' Behavior*

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Abstract

In 2003, China enacted the Road Traffic Safety Law in an attempt to promote traffic safety. We employ a difference-in-differences strategy on province level data, where fire accidents are used as a control group for road accidents, to estimate the effects of the law on road accidents and casualties. Our findings suggest that while the law was successful in decreasing the number of accidents and casualties, the ratio of deaths to accidents and injuries to accidents increased. Exploring the potential channels, we find no evidence that "hit-and-kill" incentives, that is, incentives for motorists to kill the pedestrians that they hit due to China's peculiar personal injury compensation rules, drive the increase in death to accident ratio. We show that an increase in the severity of accidents could, in fact, be consistent with a model where all motorists drive more carefully after the reform, but have heterogeneous responses such that the decrease in accident probability is larger for safer than for riskier drivers.

JEL: H54, K32, R41

Keywords: road safety regulations, traffic accidents, accident deadliness

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1 Introduction

Road accidents are among the top ten leading causes of death around the world and the number one cause of death among those aged 15 to 29 (World Bank, 2008b; WHO 2015). Almost 1.25 million people are killed and 50 million injured in road accidents each year, with pedestrians, cyclists and motorists accounting for 50% of road fatalities. Yet, according to the World Health Organization (WHO), few countries have policies that meet best practice. For instance, only 34 out of 178 countries are deemed to have best practice drunk-driving laws. Such laws are more likely to be in place among high income countries than middle or low income countries. Meanwhile, 90% of road traffic deaths occur in low and middle income countries. This suggests that road traffic safety laws may have an important role to play in curbing road casualties.

In 2003, China enacted the Road Traffic Safety Law (RTSL), China's first major law on road traffic safety. Safety standards were set, third party liability automobile insurance was made compulsory, a penalty points system was introduced, driving after drinking was prohibited, and legal responsibility was automatically attributed to motorists involved in an accident with a pedestrian or non-motorized vehicle. Data from China Statistical Yearbooks also indicate that government expenditure on public security nealy doubled after 2003, suggesting that enforcement measures could have also increased. The RTSL was expected to curb road traffic fatalities in a country that accounts for 15% of the world's road traffic deaths despite claiming only 2% of the world's motor vehicles (Zhu, 2004). In spite of such measures, the 2013 ratio of traffic deaths to accidents was 1 to 3 in China compared to a ratio of 1 to 200 in the US (CNBS, 2014; NCSA, 2015).

In this paper, we first estimate the net effects of the RTSL on road traffic accidents and casualties. We employ a difference-in-differences (DID) strategy using annual data from China Statistical Yearbooks 2000 to 2007. In particular, we exploit province and time variation in road traffic accidents and in fire accidents, in addition to controlling for a rich set of province level characteristics that may predict accidents, to identify the effects of the RTSL. We argue that fire accidents make a suitable control group for road accidents because fire accidents (excluding fires that occurred in transportation) are not affected by the RTSL and they also capture similar underlying trends. In particular, passenger traffic and electricity consumption, major factors tied to, respectively, road and fire accidents, both grew very rapidly over our sample period. Furthermore, province level attitudes towards safety and law enforcement may be similar for road and fire accidents. For instance, local officials' promotions were tied to meeting province level death ceilings or quotas on accidental deaths such that province level incentives to meet the safety standards may have been similar across road and fire accidents. Thus, the DID strategy helps identify the effects of the RTSL on road accidents net of such potentially counfounding trends.[1]

Since we use data from the China Statistical Yearbooks, fatalities in our study are defined as those occuring within seven days of an accident, in accordance with the definition employed by the Ministry of Public Security. We take potential issues associated with reporting incentives of public officials and motorists seriously. First, our DID identification strategy may help mitigate reporting issues as it differences out the similar reporting incentives trends for road and fire accidents, which are both subject to province level safety laws and regulations. Second, following Fisman and Wang (2017), we also exploit province and time variations in the introduction of death ceilings to control for potentially different reporting incentives between road and fire accidents, and find that our results are robust to such controls. Third, above and beyond our empirical analysis, we theoretically model and discuss motorists' reporting considerations.

Our findings suggest that while the RTSL seems to have successfully decreased the number of accidents and casualties, the ratio of road deaths and injuries to accidents increased after the passage of the law. This suggests that while the law was successful in decreasing the number of casualties, the deadliness of road accidents may have increased. We next explore some of the channels that may account for the increase in the deadliness of road accidents. It has been suggested that Chinese motorists may be intentionally killing the persons they hit due to China's perverse personal injury laws, whose compensation criteria may result in motorists incurring much higher costs in the case of injury than in the case of death.[2] We argue that a massive onset of hit-and-kill is unlikely to drive our results for three reasons. First, killing the victims implies leaving fewer of them injured, and thus decreases the injury to accident ratio, which is the opposite of

[1] Our line of thought in choosing fire accidents as a control group for road accidents is somewhat similar to Levitt (2002), who estimates the effects of policemen on crime and uses firefighters as instruments for policemen, with the notion that municipal level factors such as the power of public sector unions and citizen tastes are likely to be common to both types of civil servants. Similarly, Gross and Notowidigdo (2011) use business bankruptcies as a control for personal bankruptcies in their analysis on the expansion of Medicaid on personal bankruptcies.

[2] The media has reported anecdotal evidence on the hit-and-kill phenomenon, for which there is even a Chinese adage: "It is better to hit to kill than to hit and injure". For example, a Slate magazine article documents that "security cameras have regularly captured drivers driving back and forth on top of victims to make sure that they are dead" and attributes this phenomenon to the fact that it is cheaper to kill than to injure: "In China the compensation for killing a victim in a traffic accident is relatively small - amounts typically range from \$30,000 to \$50,000 - and once payment is made, the matter is over. By contrast, paying for lifetime care for a disabled survivor can run into the millions" (Sant, 2015; see also Li and Dong, 2007; Mao, 2008; Zhou, 2013). Insurance compensation also tends to be relatively low such that liable motorists may bear very high out-of-pocket costs in the case of severe injury. Approximately 70% of road fatality victims in China comprise of pedestrians and non-motorized vehicle and motorcycle users while 61% of fatalities are caused by trucks, buses and cars (World Bank, 2008b).

what we find. Second, we conjecture that if hit-and-kill incentives are driven by compensation considerations, then provinces with higher health care prices should experience greater increases in the death to accident ratio after the passage of the RTSL, which we do not find. Third, we find no evidence that the ratio of fatalities to accidents involving vulnerable road users, such as pedestrians or cyclists, increased after the RTSL. Altogether, we find no evidence that suggests that hit-and-kill incentives drive the increase in accident deadliness.

We theoretically show that the presence of heterogenous motorists who all drive more carefully after the passage of the law could, in fact, be consistent with both a reduction in the number of accidents and casualties, as well as an increase in the severity of road accidents. In particular, if safer drivers are more responsive to the RTSL, such that they face a greater decrease in the probability of getting into an accident compared to riskier drivers, then less severe accidents may decrease by a larger proportion such that the ratio of severe accidents to all accidents increases. We further explore and discuss related mechanisms that could be consistent with our empirical results, such as changes in the composition of motorists on the road and heterogeneous changes in the distribution of accident damages. Our findings suggest that the increase in the ratio of deaths to accidents may be a red herring in the evaluation of road traffic safety laws if the policy goal is to encourage all motorists to drive more carefully. Conversely, if policy goals also include decreasing the severity of the remaining accidents, then targeting the underlying source of heterogeneity, such as drunk or speeding drivers, may be important.

A strand of the literature that is particularly relevant in our context is one that considers changes to road safety laws, automobile insurance, and accident liability. Peltzman (1975) argues that more stringent safety regulations may encourage motorists to drive more recklessly as they feel safer. Conversely, DeAngelo and Hansen (2014) find that a decrease in police enforcement leads to an increase in injuries and fatalities and attributes this to increased reckless driving while Luca (2014) finds that an increase in traffic tickets reduces accidents and non-fatal injuries. In a similar vein, Carpenter and Stehr (2008), Cohen and Einav (2003), and Lindgren and Stuart (1980) find that better safety regulations, such as mandatory regular vehicle safety checks, seat belts laws and speed limits, lead to a reduction in road fatalities in the US and in Sweden.

Cohen and Dehejia (2004) exploit state and time variation in the introduction of compulsory automobile insurance to assess the moral hazard costs of insurance. They find that auto insurance combined with no-fault liability laws lead to an increase in traffic fatalities in the US. Levitt and Porter (2001) show that drunk drivers are more likely to cause fatalities and quantifies an optimal drunk driving fine. Similarly, Dee (2001) finds that alcohol limits reduce traffic fatalities while

Hansen (2015) finds that sanctions are effective in reducing recidivism in drunk driving. Conversely, Ruhm (1996) reports that alcohol-control policies have little impacts on road fatalities but that higher beer taxes lead to a reduction in fatalities in the US. The broader literature has also explored the effect of marijuana legalization (Anderson et al., 2013), mileage and gasoline taxes (Parry, 2004; Parry and Small, 2005), text messaging laws (Abouk and Adams, 2013), and fuel economy standards (Jacobsen, 2013) on road accidents and casualties.

Our paper also relates to the literature that investigates the interaction of motorists' preferences and road safety laws in shaping outcomes such as accidents, injuries, and fatalities. Verhoef and Rouwendal (2004) present a model of traffic congestion, where homogenous motorists choose the optimal speed according to expected accidents costs, and present a case for tolls and speed policies. Van den Berg and Verhoef (2011) analyze a model where motorists have heterogeneous values of time to investigate the distributional impacts of congestion policies. In a similar vein, Small et al. (2005) find that there is considerable heterogeneity in motorists' value of time and argue for differentiated road pricing while Traxler et al. (2018) employ a model with heterogeneous motorists to show that bunching may occur in a stepwise speeding penalty system.

To the best of our knowledge, this paper is the first that provides evidence that traffic safety laws may decrease the number of accidents and casualties while at the same time result in an increase in the deadliness of accidents. We show that the increase in deadliness of road accidents may not necessarily be the result of moral hazard that results in reckless driving or in deliberate murder. Rather, an increase in the deadliness of road accidents may still be consistent with improved road safety and careful driving. This result is driven by a combination of road safety laws that make infractions costlier and by the heterogeneity in motorists' responses. Our paper provides a cautionary tale on the evaluation and design of safety and personal injury laws in the presence of heterogeneity.

Section 2 presents the legal background of the RTSL and personal injury laws. In Section 3, we discuss our identification strategy and in Section 4, we estimate the effects of the RTSL on accidents and casualties using a DID strategy. We then attempt to identify whether hit-and-kill incentives drive our results, and perform sensitivity analyses that account for the possibility that local officials may have different incentives to manipulate road and fire fatalities data. We show that the findings would be consistent with a model where motorists may have heterogeneous reponses to the reform and discuss alternative mechanisms such as changes in driver composition or in the distribution of damages in Section 5. We conclude in Section 6.

2 Background

We describe the main components of the Road Traffic Safety Law (RTSL) and of the compensation criteria for personal injury, and discuss the implications of the introduction of the law for motorists.

2.1 Road Traffic Safety Law

In October 2003 and April 2004, China enacted the RTSL and promulgated its administrative regulations, respectively, both of which concurrently took effect on 1 May 2004. This was China's first ever law on road traffic safety and it set safety standards, made third party liability automobile insurance compulsory, introduced a penalty points system, prohibited drunk driving, and specified legal responsibility in accidents.

Safety Uniform road traffic signals including traffic signal lamps, traffic signs and traffic line markings are to be applied throughout the country (RTSL, 2003, Art. 25). Drivers and passengers are required to wear safety belts in a running motor vehicle (RTSL, 2003, Art. 51). Motor vehicles are subject to regular safety technical inspections (RTSL, 2004, Art. 16). Those that do not comply with the national safety standards are fined between 5 to 10 times the inspection fees and are subject to criminal liabilities (RTSL, 2003, Art. 94). The maximum speed limit on expressways is set at 120 km per hour (RTSL, 2003, Art. 67).

Insurance All motor vehicles have to be covered by the Statutory Automobile Liability Insurance (SALI). Those who fail to purchase the compulsory third party liability insurance are liable to pay a fine of twice the insurance premium payable at the minimum liability limit (RTSL, 2003, Art. 98). Proof of mandatory third party liability insurance is required for motor vehicle registration and for regular motor vehicle safety technical inspections. The inspection mark and insurance sign need to be displayed on the motor vehicle (RTSL, 2004, Art. 5, 13, 17).

SALI has a uniform premium nationwide and renewal premiums are experience-rated according to the number of accidents and fines incurred in the previous year. While SALI covers third party liability for death, injury and medical expense, and property loss, the nationwide limits of liability are relatively low. If the insured is at fault [not at fault], the limits are 50,000 yuan [10,000 yuan], 8,000 yuan [1,600 yuan], and 2,000 yuan [400 yuan] for death, medical expense and property loss, respectively (Jing, 2016; Yao and Qian, 2007).

Penalty points system The RTSL introduced a cumulative penalty points system (RTSL, 2003, Art. 23). Upon accumulating 12 points over a 12 month period, a motorist's license is suspended until the motorist passes an exam on traffic safety. Should the motorist score fewer than 12 points over a 12 month period, then the scores are cleared if the motorist pays all due fines but are carried forward to the next period if the motorist has unpaid fines. In addition, if the motorist scores fewer than 12 points every year during the license validity period, then the motorist's license is replaced with one with a longer validity period (RTSL, 2004, Art. 23-26).

Drunk driving Driving after the consumption of alcohol is prohibited under the RTSL. Penalties for motorists driving after drinking consist of a fine of 200-500 yuan and a 1-3 months driving license suspension. Penalties for motorists driving intoxicated constitute of a fine of 500-2000 yuan and a 3-6 months license suspension, and detention of up to 15 days. In addition, motorists who are penalized for driving intoxicated twice or more within one year will have their driving license cancelled (RTSL, 2003, Art. 22, 91). According to the WHO, China's drink driving limits follow best practice, that is, blood alcohol concentration (BAC) limit of 0.05 g/dl for the general population and BAC limit of 0.02 g/dl for young or novice drivers (WHO, 2015).

Accidents If an accident occurs and results in personal injury, the motorist is responsible for rescuing the injured and calling the police. When an accident occurs between a motor vehicle and a non-motorized vehicle or pedestrian, the motorist is automatically liable unless there is evidence the other party violated traffic laws, in which case, the motorist's liabilities may be mitigated. A motorist who flees away from an accident will automatically be held responsible, in addition to having to pay a fine and having his driving license revoked indefinitely. Witnesses who report the accident are rewarded (RTSL, 2003, Art. 70, 71, 76, 99, 101; RTSL, 2004, Art. 88-92).

2.2 Compensation for Personal Injury

The "Interpretation of the Supreme People's Court of Some Issues Concerning the Application of Law for the Trial of Cases on Compensation for Personal Injury" was adopted in December 2003 and came into force in May 2004 (Supreme People's Court, 2003). According to Article 17 of the Interpretation, compensation for injury victims should include medical expenses, work income loss and nursing expenses. Compensation for disability victims should include injury compensation and follow up treatment expenses, disability compensation, and the living expenses of the dependents. Compensation for fatality victims who die at the scene of an accident should include funeral related expenses, death compensation, and the living expenses of the dependents. Details on each component are as follows:

Medical expenses are based on invoices of expenses incurred at medical institutions (Art. 19). If the victim requires treatment in another place in the country, accommodation and board expenses of the victims and carers are also included (Art. 23).

Work income loss are based on the victim's missed working time and usual income. If the victim becomes disabled, the missed working time may be calculated up to the day prior to the disability diagnosis (Art. 20).

Nursing expenses are based on the usual income of the nursing personnel and the nursing period. The nursing personnel may be from a nursing agency or may be a family member and the nursing period may last up to 20 years (Art. 21).

Disability compensation is based on the grade of disability and per capita disposable income of the local population for a period of up to 20 years. Disabilities are classified into 10 grades ranging from 10% to 100%. Disability compensation is computed as $A \times B \times C$. A is per capita income of the local population in the previous year; B is the disability grade percentage ($\div$ 100); and $C = 20$ if the victim is aged less than 60, $C = 20 - n$ if the victim is aged $60 + n \leq 75$, and $C = 5$ if the victim is aged above 75 (Art. 25).

Death compensation is computed as $A \times C$ as defined above (Art. 29).

Funeral related expenses are computed as $0.5A$ as defined above (Art. 27).

Living expenses of dependents are based on per capita consumption of the local population for a period of up to 20 years (Art. 28). Living expenses are computed as $D \times E$. D is per capita consumption of the local population in the previous year; E is the number of years up to 18 if the dependent is a minor, and $E = C$ as defined above if the dependent is an adult with no ability to work and no other source of income.

2.3 Implications for Motorists

The RTSL provides "carrot and stick" type incentives that make infractions costlier for motorists. On one hand, good driving behavior is rewarded through lower insurance premiums under SALI and through an increase in the validity period of driving permits under the penalty points system. On the other hand, bad driving behavior is punished through increased insurance premiums under SALI, the need to retake driving tests under the penalty points system, and increasing fines and potential license cancellation under the drunk driving laws.

In addition, the combination of motorists' liability in the case of an accident and compensation to victims under the personal injury laws increased the expected costs of getting into an accident. Since the insurance limits under SALI tend to be relatively low, motorists may still have to bear very high out-of-pocket costs. While motor vehicle owners may also purchase additional commercially available third party liability insurance, the majority of such policies provide a limit of up to 100,000 yuan. Willis Pudong Insurance Brokers, one of the largest insurance brokers in the world, recommend an insurance limit of 500,000 yuan in the light of recent Chinese court case outcomes (Willis Pudong Insurance Brokers, 2006). Approximately 50% of road accident cases involving injury or death documented on CaseShare involved insurance compensation. On average, insurance covered 35.4% of compensation suggesting that most compensation were covered out-of-pocket.[3]

Altogether, the RTSL made driving infractions as well as the expected costs of getting into an accident costlier for motorists. Thus, we expect the RTSL to have encouraged motorists to drive more carefully, which may lead to a fall in the number of accidents and casualties. Below, we present our identification strategy and estimate the net effects of the law on road accidents and casualties. Since all of the legal components were implemented simultaneously at the national level, we estimate the net effects of the law and do not attempt to disengangle the effects of the separate components described above. We then present a formal model of motorist behavior and discuss the potential channels that may drive our empirical results.

3 Trends and Identification

This section describes the trends in road accidents and casualties using data from China Statistical Yearbooks corresponding to years 2000 to 2007. We focus our main analysis on this sample period because of the lack of province level data in earlier years, which would also overlap with the 1998 Asian financial crisis. We then discuss the identification strategy, which employs a difference-in-differences (DID) approach that exploits time variation (before and after the reform) and province level accident type variation (road and fire), in addition to controlling for a rich set of province level characteristics that may affect the two types of accidents, to identify the effects of the RTSL on road accidents and casualties.

[3] Authors' computations based on 43 court cases documented on CaseShare as of 20 March 2016.

3.1 Road Traffic Accident Trends

We illustrate road traffic accident trends in China before and after the enactment of the 2003 RTSL in Figure 1. The top panels illustrate the number of accidents, deaths and injuries per 10,000 persons. The variables are summed across all provinces excluding Tibet. The bottom panels illustrate the ratios of deaths and injuries to accidents. As can be seen from the top panels, there seems to have been a decrease in the number of accidents, deaths and injuries after the introduction of the RTSL.[4] Conversely, as can be seen from the botton panels, there seems to have been a sharp increase in the death to accident and injury to accident ratios after the introduction of the RTSL. Similarly, Appendix Figure A1 illustrates that while the number of serious accidents and deaths and injuries arising from serious accidents seem to have decreased, the proportion of serious accidents to total accidents seems to have increased while the ratio of deaths and injuries arising from serious accidents to the number of serious accidents increased after the passage of the RTSL.[5] The trends seem to suggest that while the RTSL may have been effective in reducing the number of accidents, the seriousness of accidents may have increased after the passage of the law. Similar patterns emerge across China's provinces as can be seen from Appendix Figures A2 to A6.

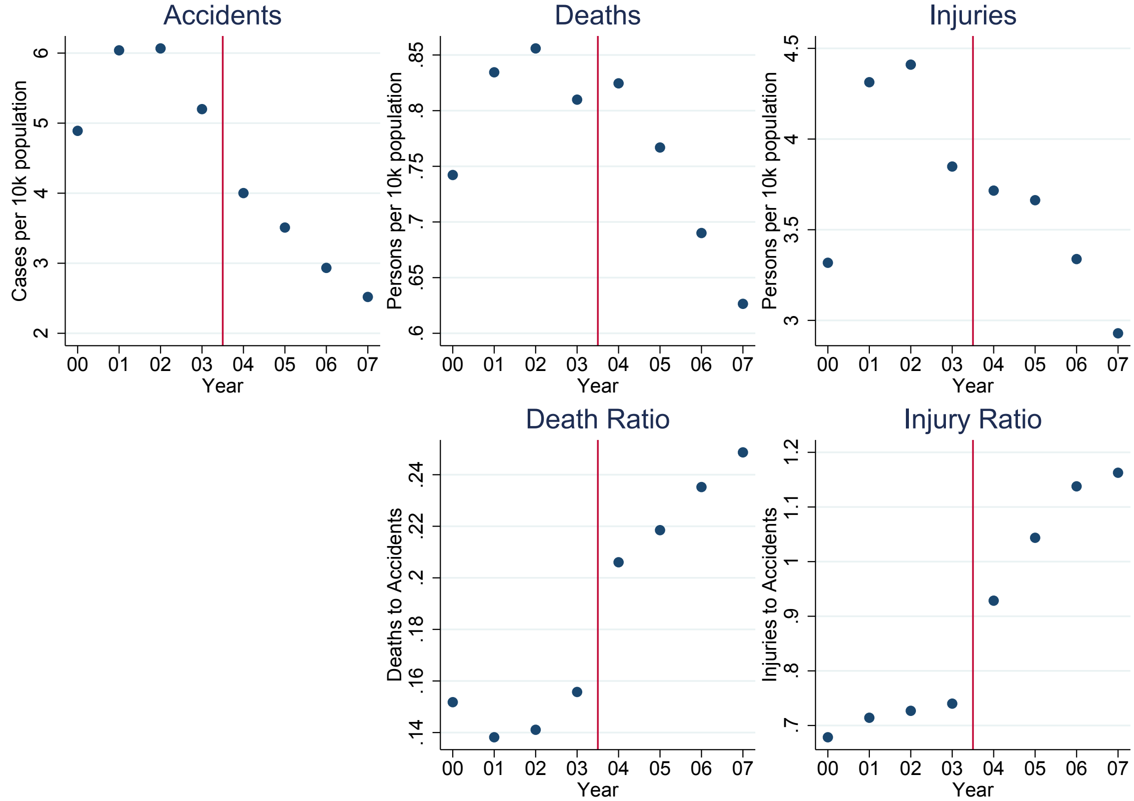
3.2 Identification

Identifying the effects of the RTSL separately from other trends is a challenging task. In particular, simply comparing road accidents and casualties before and after the national reform may capture not only the effect of the RTSL but also the effect of other related factors that may have changed during that period. Whereas our data set enables us to control for a rich set of economic and traffic related variables that may also contribute to road accidents and casualties, we cannot control for other unobserved confouding factors such as province level trends in general attitudes towards safety. We, therefore, employ a DID strategy to identify the effect of RTSL on road accidents and casualties. In particular, we exploit province level variations in road traffic accidents and in fire accidents (excluding fires incurred in transportation), in addition to controlling for province level characteristics that may predict accidents and casualties.

[4] The increase in the number of accidents and casualties prior to the RTSL possibly relates to the rapid GDP growth experienced by China after the 1998 Asian financial crisis. As described below, we control for time varying province level characteristics such as real GDP and passenger traffic in our empirical analysis.

[5] Data on such accidents are available only at the national level. While China Statistical Yearbooks do not define serious accidents, we conjecture that such definition is based on some threshold level of severity such as serious injury or fatality. For example, China's State Administration of Worker Safety defines serious accidents as those involving 3 or more deaths in one accident.

Figure 1: Road Traffic Accidents in China

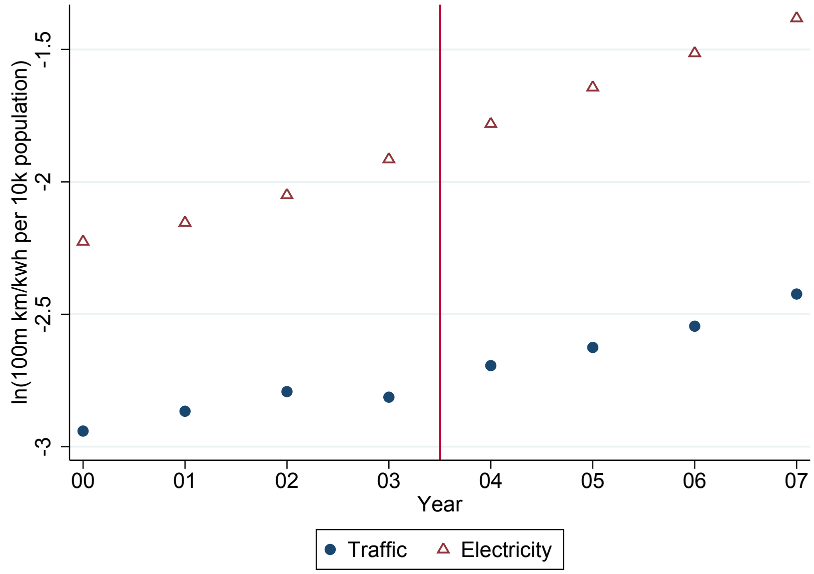


Note: The top panels illustrate the total number of accidents, deaths and injuries per 10,000 persons. The bottom panels illustrate the ratios of deaths and injuries to total accidents. The vertical line illustrates when the RTSL was enacted.

We argue that fire accidents make a suitable control group for road accidents because fire accidents are unlikely to have been affected by the RTSL. Furthermore, we posit that fire accidents have similar underlying trends as road accidents for two reasons. First, per capita passenger traffic and electricty consumption both grew rapidly over our sample period, during which China also experienced rapid economic growth. Traffic congestion is known to be a major driving factor behind road accidents (Green et al., 2016; Romem and Shurtz, 2016) whereas electrical failure is one of the major causes behind fire accidents in China (Pan et al., 2012; Xin and Huang, 2014). Figure 2 plots the growth trends in passenger traffic (100m km per 10,000 persons) and in electricity consumption (100m kwh per 10,000 persons). As can be seen from the Figure, both per capita passenger traffic and electricity consumption grew rapidly, suggesting that major risk factors for road and fire accidents, respectively, increased rapidly over our sample period. As elaborated on in Section 3.3, we also control for such variables in our empirical analysis.

Second, province level attitudes towards safety and legal enforcement are likely to be similar

Figure 2: Growth in Passenger Traffic and Electricity Consumption



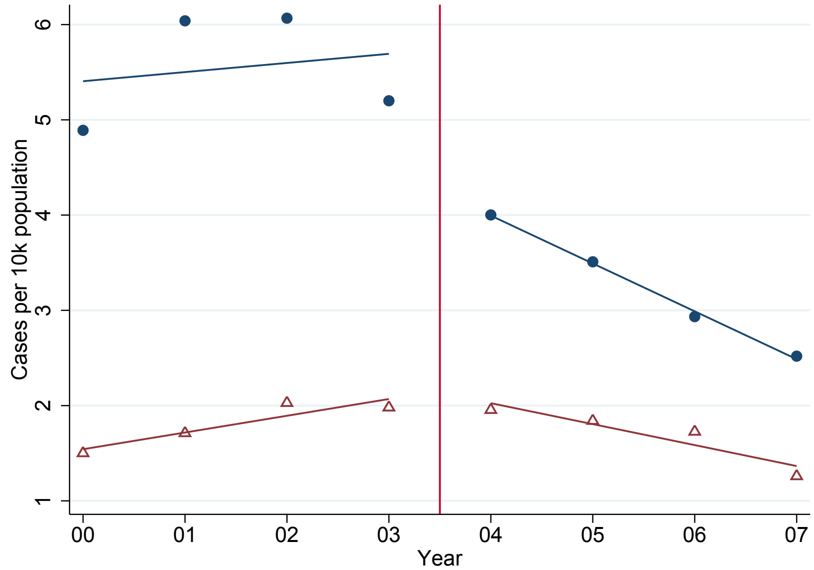
Note: Passenger traffic is measured in logarithm of 100m km per 10,000 persons and electricity consumption is measured in logarithm of 100m kwh per 10,000 persons.

across road and fire accidents. Traffic violation is another major cause of road accidents (Zhang et al., 2014) whereas fire misuse is another major driver in fire accidents (Pan et al., 2012; Xin and Huang, 2014), suggesting that carelessness or recklessness is linked to both types of accidents. Furthermore, the State Council of China also emphasized the importance of enhancing workplace safety in 2004. Whereas the rules targeted mostly work place deaths, province level death ceilings or quotas were also imposed on road and fire deaths. Some provinces imposed "no safety, no promotion" rules that made promotion of local government officials contingent on meeting the death ceilings. Deaths to ceilings ratios were very similar across road and fire accidents (≈ 0.94 and 0.93, respectively, in Fisman and Wang, 2017, Table 1), suggesting similar regulation standards across the two types of accidents.[6]

Our line of thought in choosing fire accidents as a control group for road accidents is somewhat similar to Levitt (2002) who employs different types of civil servants to estimate the effects of policemen on crime, and to Gross and Notowidigdo (2011) who use different types of bankruptcies to estimate the effects of Medicaid on personal bankruptcies. Levitt (2002) uses the number of firefighters to predict the number of policemen in a given municipality, since municipal level factors such as the power of public sector unions and citizen tastes are likely to affect both types

[6]We further address the issue of death ceilings in Section 4.3.

Figure 3: Trends in Road and Fire Accidents in China



Note: The circles illustrate the number of road accidents per 10,000 persons and the triangles illustrate the number of fire accidents per 10,000 persons.

of civil servants in a similar fashion. Gross and Notowidigdo (2011) use business bankruptcies as control for personal bankruptcies since Medicaid is expected to affect only personal bankruptcies while both types of bankruptcies may be influenced by similar underlying economic forces.

Figure 3 illustrates the trends in road and fire accidents summed accross all provinces (excluding Tibet) in China. As can be seen from the figure, the pre-RTSL trends seem to be similar across road and fire accidents. Furthermore, while the death ceilings may have affected road and fire accidents, the RTSL seems to have reinforced the drop in road accidents, thereby generating a steeper decline in the latter. Table 1 reports the means and standard deviations for the number of accidents per 10,000 persons, deaths per 10,000 persons, injuries per 10,000 persons, death ratio and injury ratio across road and fire accidents. The variables are summarized across all provinces excluding Tibet for years 2000-2003 and for years 2004-2007. As can be seen from the table, while there seems to have been a decrease in the number of accidents, deaths, and injuries, and an increase in death ratio and injury ratio for road accidents after the reform, no such patterns seem to emerge for fire accidents.[7]

We perform a simple test of the hypothesis that the pre-RTSL trends were the same for road and

[7] We report road and fire accidents and casualties for each province in Appendix Figures A2 to A6. As can be seen from the graphs, whereas the RTSL seems to have affected road accidents and casualties, it does not seem to have affected fire accidents and casualties in most provinces.

fire accidents using province level regressions on years prior to the RTSL.[8] The tests are performed with the following outcome variables in levels, $Y = y$, and in natural logarithm, $Y = ln(y+1)$: Accidents per 10,000 persons, deaths per 10,000 persons, injuries per 10,000 persons, death ratio, and injury ratio. We could never reject the hypothesis that the pre-RTSL trends were the same for road and fire accidents and casualties at the 5% statistical significance level. This gives us some confidence that our DID strategy, elaborated on below, helps in identifying the effects of the RTSL on road accidents net of potentially counfounding trends driven by attitudes towards safety or death ceilings that are captured by fire accidents.

We perform further validity checks on the pre-RTSL trends between road and fire accidents in Section 4.4. In particular, we perform regressions that control for province and time varying characteristics (described below) that may affect road and fire accidents differentially. The results of these still show that there were relatively large and statistically significant changes ($p < .05$) in road accident outcomes only post 2003. We also perform a placebo test using national level data from earlier years in Section 4.4.

3.3 Control Variables

In our empirical analysis, we control for time varying province level characteristics that may predict accidents and casualties, and allow such controls to affect road and fire accidents differentially.

Demographic variables Demographic composition may correlate with accident risks within a province. Edlund et al. (2013) find that sex ratios are positively associated with crime while Sandamarina-Rubio et al. (2014) and Zhang et al. (2014) find that men are more likely to be involved in an accident and have higher road fatality risk than women. De Raedt and Ponjaert-Kristoffersen (2001) document that older drivers are more likely to make attention and perception errors than younger drivers whereas Sami et al. (2013) finds that age and education correlate with road fatality rates. Demographic controls include population in 10,000 persons, sex ratio: number of males to number of females, aged dependency ratio: number of persons aged 65 and above to number of persons aged 15-64, and number of college educated per 10,000 persons. From Table 1,

[8] In particular, we estimate the following model for each accident group, g = road or fire: $Y_{gpt} = \beta_{0g} + \beta_{1g}Year_t + \varepsilon_{gpt}$; Y_{gpt} denotes the outcome variable related to accident type g in province p and year t, $Year_t$ captures a linear trend for years prior to 2004, and ε_{gpt} is an error term. The estimates for road and fire accidents are combined as seemingly unrelated estimations, and the hypothesis that the trends were similar across road and fire accidents is tested: $H_0: \ \beta_{1road} = \beta_{1fire}$.

Table 1: Summary Statistics

	2000-2003		2004-2007	
	Mean/Pr.	(s.d)	Mean/Pr.	(s.d)
Road accidents				
No. of accidents per 10k persons	6.43	(5.58)	3.33	(2.13)
No. of deaths per 10k persons	0.86	(0.32)	0.78	(0.30)
No. of injuries per 10k persons	4.23	(2.37)	3.45	(1.96)
Death ratio: deaths to accidents	0.18	(0.08)	0.28	(0.12)
Injury ratio: injuries to accidents	0.75	(0.16)	1.07	(0.17)
Fire accidents				
No. of accidents per 10k persons	2.25	(1.92)	2.19	(1.72)
No. of deaths per 10k persons	0.02	(0.01)	0.02	(0.01)
No. of injuries per 10k persons	0.03	(0.01)	0.02	(0.02)
Death ratio: deaths to accidents	0.01	(0.01)	0.01	(0.01)
Injury ratio: injuries to accidents	0.02	(0.01)	0.01	(0.01)
Demographic variables				
Population in 10k persons	4232.01	(2568)	4297.27	(2599)
Sex ratio: males to females	105.67	(3.15)	103.00	(2.94)
Aged dependency ratio	11.21	(2.55)	12.32	(2.34)
No. of college educated per 10k persons	0.05	(0.04)	0.07	(0.05)
Economic and enforcement variables				
GDP per 10k persons (100m yuan)	1.30	(0.80)	2.23	(1.42)
Prop. of employed living in urban areas	0.14	(0.07)	0.16	(0.08)
Public security per 10k persons (1m yuan)	1.24	(0.88)	2.34	(1.60)
Medical variables				
No. of hospital beds per 10k persons	27.43	(8.75)	28.88	(8.40)
No. of medical personnel 10k persons	38.41	(12.95)	38.53	(12.12)
Traffic related variables				
Passenger traffic per 10k persons (10k km)	0.05	(0.02)	0.07	(0.03)
Freight traffic per capita (10k tons-km)	0.06	(0.02)	0.08	(0.03)
No. of motor vehicles per 10k persons	0.02	(0.02)	0.03	(0.03)
No. of trucks per 10k persons	0.01	(0.00)	0.01	(0.00)
No. of auto drivers per 10k persons	0.04	(0.03)	0.07	(0.04)
No. of street lights per sqm of paved road	27.13	(8.06)	35.75	(11.78)
Building related variables				
Electricity per 10k persons (100m kwh)	0.15	(0.08)	0.24	(0.14)
City residential floor space per capita (sqm)	20.35	(4.58)	25.68	(33.70)
No. of construction personnel per 10k persons	172.00	(90.23)	208.30	(132.2)
No. of province-year observations	120		120	

Note: Data from China Statistical Yearbooks 2000 to 2007. Means, proportions and standard errors are reported across all provinces excluding Tibet. Monetary variables are converted to 2013 prices using the consumer price index (CPI).

the average population, the aged dependency ratio, and number of college educated persons seem to have increased while the ratio of males to females seems to have decreased over time.

Economic and enforcement variables Economic growth and urbanization may also contribute to accidents and fatalities. Iwata (2010) finds that GDP is correlated with traffic fatalities, which could be due to the fact that more people drive as the economy grows, while Iamtrakul and Hokao (2012) find a negative correlation between urbanization and road safety. Economic controls thus include real GDP per 10,000 persons and the proportion of employed individuals living in urban areas. As can be seen from Table 1, both GDP per capita and the proportion of employed individuals living in urban areas seem to have increased over time. As police enforcement may also predict road accidents and fatalities (DeAngelo and Hansen, 2014; Luca, 2014), we further control for real government expenditure on public security per 10,000 persons in our analysis. This measure includes expenditure on armed police force, state security, prosecution, courts, and prison. From Table 1, there seems to have been large increases in public security expenditure, which nearly doubled post 2003.

Medical variables Quality of health care has also been identified as an important factor in accident fatalities (Gopalakrishnan, 2012, WHO, 2015). Thus, we also control for medical variables such as the number of hospital beds per 10,000 persons and number of medical personnel per 10,000 persons. As can be seen from Table 1, the number of hospital beds and medical personnel seem to have slightly increased post 2003.

Traffic related variables Green et al. (2016) and Romem and Shurtz (2016) find evidence suggesting that increased congestion is associated with greater road accidents. Anderson (2008) and White (2004) find that increases in the number of trucks on the road may increase road fatalities. We, therefore, control for passenger traffic, freight traffic, number of motor vehicles, trucks and automobile drivers per 10,000 persons. We further control for the number of street lights per square meter of paved road in our analysis, which may help capture the quality of roads over time and across provinces. From Table 1, those variables seem to have increased over time.

Building related variables Pan et al. (2012) and Xin and Huang (2014) find that electrical failure is a major cause of fire accidents and that such accidents are more prevalent in residential buildings. We thus control for electricity consumption per 10,000 persons, per capita city residential floor space, and number of construction personnel per 10,000 persons. As can be seen from Table 1, those factors seem to have increased post 2003.

Exploiting fire accidents as a control group and additionally controlling for characteristics that may affect road and fire outcomes differentially can help mitigate some of the concerns associated with potential confounding factors. To the extent that other unobserved factors beyond our controls may have influenced outcomes, our results must be interpreted with caution.

4 Effects of the RTSL on Road Accidents and Casualties

Section 4.1 estimates the effects of the RTSL on road accidents and casualties using a DID model. Investigating some of the potential channels behind our results, we analyze whether motorists may have an incentive to intentionally kill their victims in Section 4.2. Section 4.3 addresses the concern that local officials may have different incentives to manipulate road and fire fatalities reports. Further validity checks are performed in Section 4.4.

4.1 Baseline Analysis

We estimate the following model:

$$Y_{gpt} = \beta\,(A_g \times RTSL_t) + \theta' X_{gpt} + \mu_g + \mu_p + \mu_t + \varepsilon_{gpt}. \tag{1}$$

Y_{gpt} denotes the outcome variable related to accident group g, province p and time t; A_g is a dummy variable taking a value of 1 for road related accidents and a value of 0 for fire related accidents; $RTSL_t$ is a dummy variable taking a value of 1 for years after the RTSL, that is, for years 2004 onwards, and a value of 0 otherwise; X_{gpt} is a vector of accident type, province and year varying covariates; μ_g is an accident type dummy inclusive of A_g; μ_p is a vector of province dummies; μ_t is a vector of year dummies inclusive of $RTSL_t$ and dummies for years 2001, 2002, 2003, 2006, 2007;[9] and ε_{gpt} is an error term. We cluster the standard errors at the province level.[10]

[9]Note that dummies for years 2000 and 2005 are omitted due to collinearity.

[10]We also performed sensitivity analyses by clustering at a higher geographic level and using wild cluster bootstrap to account for the small number of clusters (Cameron et al., 2008; Cameron and Miller, 2015). In particular, the standard errors were clustered at the (i) six great administrative areas level and (ii) accident group and adminstrative areas level, which generated the same inferences as those reported below.

The parameter of interest, β, captures the effect of RTSL on outcomes related to road accidents. The outcome variable is defined in levels, $Y_{gpt} = y_{gpt}$, or in natural logarithm, $Y_{gpt} = ln(y_{gpt} + 1)$,[11] where y_{gpt} denotes the number of road accidents, deaths and injuries per 10,000 persons, and the ratios of deaths and injuries to accidents. The vector of control variables, X_{gpt}, includes demographic, economic and enforcement, and medical variables described above, as well as their interaction terms with A_g, such that they may affect road and fire related outcomes differentially. X_{gpt} also includes interaction terms between A_g and the traffic related variables that may influence road related outcomes, as well as interaction terms between $(1 - A_g)$ and the building related variables that may influence fire related outcomes.

Table 2 presents the effects of RTSL on road accidents and casualties. Columns (1) to (3) report the estimated β from Model (1), with the dependent variables specified in levels while Columns (4) to (6) report the estimated β, with the dependent variables specified in logarithm. We report results controlling for province and year fixed effects in Columns (1) and (4), additionally controlling for the time and group varying province level variables in Columns (2) and (5), and further controlling for linear province specific trends in Columns (3) and (6).[12]

As can be seen from Column (1) of Table 2, the RTSL seems to have led to a decrease in the number of road accidents, deaths and injuries by, respectively, 3.038 cases, 0.076 deaths, and 0.767 injuries per 10,000 persons. This corresponds to a decrease of, respectively, 47%, 8.8% and 18% relative to the pre-reform levels. Conversely, there seems to have been a 10.2 percentage point increase in the ratio of deaths to accidents and a 33.6 percentage point increase in the ratio of injuries to accidents. This corresponds to an increase of, respectively, 56.7% and 44.8% relative to the pre-reform ratios. The results are qualitatively robust and statistically significant at the 5% level across all specifications in Columns (2) to (6). Thus, the introduction of the RTSL seems to have led to a decrease in the number of accidents, deaths and injuries but to an increase in the ratio of deaths and injuries to accidents. This seems to confirm the trends documented earlier: While the number of accidents and casualties seem to have decreased with the RTSL, the deadliness of road accidents seems to have increased.

[11] Sensitivity analyses using different scaling factors between 0 and 1, in increments of 0.1 in the logarithmic function, yielded qualitatively and statistically significantly similar results to those reported below.

[12] The results were robust to controlling for a second order polynomial in the province specific trends.

Table 2: Effects of Road Traffic Safety Law on Road Accidents and Casualties

	Levels			Logarithm		
	(1)	(2)	(3)	(4)	(5)	(6)
Accidents per 10k						
$A_g \times RTSL_t$	-3.038**	-4.004**	-3.814**	-0.455**	-0.505**	-0.505**
	(0.771)	(0.936)	(0.882)	(0.064)	(0.087)	(0.088)
R-squared	0.59	0.75	0.78	0.78	0.87	0.88
Deaths per 10k						
$A_g \times RTSL_t$	-0.076**	-0.168**	-0.167**	-0.039**	-0.087**	-0.088**
	(0.026)	(0.044)	(0.045)	(0.014)	(0.022)	(0.022)
R-squared	0.88	0.95	0.95	0.93	0.97	0.97
Injuries per 10k						
$A_g \times RTSL_t$	-0.767**	-1.483**	-1.434**	-0.141**	-0.274**	-0.274**
	(0.250)	(0.417)	(0.425)	(0.040)	(0.059)	(0.063)
R-squared	0.77	0.88	0.89	0.93	0.96	0.97
Death ratio						
$A_g \times RTSL_t$	0.102**	0.109**	0.111**	0.082**	0.088**	0.089**
	(0.011)	(0.018)	(0.020)	(0.008)	(0.013)	(0.014)
R-squared	0.85	0.90	0.91	0.88	0.92	0.93
Injury ratio						
$A_g \times RTSL_t$	0.336**	0.320**	0.313**	0.182**	0.175**	0.171**
	(0.025)	(0.045)	(0.047)	(0.014)	(0.026)	(0.027)
R-squared	0.96	0.97	0.97	0.97	0.98	0.98
N	480	480	480	480	480	480
Controls						
Covariates		x	x		x	x
Province trend			x			x
Year FE	x	x	x	x	x	x
Province FE	x	x	x	x	x	x

Note: Covariates include demographic variables: Population in 10,000 persons, sex ratio (males to females), aged dependency ratio (age 65 and above to age 15-64), number of college educated per 10,000 persons; Economic and enforcement variables: Real GDP per 10,000 persons, proportion of employed individuals living in urban areas, Real government expenditure on public security per 10,000 persons; Medical variables: Number of hospital beds and number of medical personnel per 10,000 persons; Traffic related variables: Passenger traffic, freight traffic, number of motor vehicles, trucks and automobile drivers per 10,000 persons, and number of street lights per sqm of paved road; Building related variables: Electricity consumption per 10,000 persons, per capita city residential floor space, and number of construction personnel per 10,000 persons. Standard errors are clustered at the province level. † $p < .1,^{*}$ $p < .05,^{**}$ $p < .01$.

4.2 Hit-and-Kill Incentives?

Popular culture suggests that motorists may be intentionally killing their victims to avoid the high out of pocket costs associated with injury. Anecdotal accounts and videos of motor vehicles driving back and forth on their victims have been put forth to support the phenomenon.[13] There is even a Chinese adage on the matter: "It is better to hit to kill than to hit and injure" (Li and Dong, 2007; Mao, 2008; Sant, 2015; Zhou, 2013).

As documented in Section 2, responsibility is attributed to motorists in case of accidents involving non-motorized vehicles or pedestrians. In addition, the main difference between compensation payment in case of full disability and in case of instant death at the scene of an accident arises from the difference between injury compensation (medical and follow-up expenses, work income loss prior to disability diagnosis, nursing expenses of up to 20 years) and funeral expenses (6 months per capita income of the local population). One may, therefore, speculate that a motorist involved in such an accident may have an incentive to kill the victims that they hit in order to avoid incurring potentially high compensation costs. Whereas third-party liability insurance was made compulsory under the RTSL, as discussed above, insurance compensation tends to be relatively low such that motorists may still bear very high out-of-pocket costs. If motorists were indeed killing their victims in order to avoid paying compensation to disabled victims, we would thus expect an increase in the death to accident ratio after the RTSL.

We present three pieces of evidence that suggest that hit-and-kill incentives are not major drivers behind our results. First, if there is indeed a massive onset of hit-and-kill, then killing the victims on the accident site would imply leaving fewer of them injured such that the injury to accident ratio should decrease. This is not consistent with our findings that injury ratio increases in Table 2, and especially in serious accidents as documented in Appendix Figure A1.

Second, one would expect hit-and-kill incentives to be higher in provinces with high health costs, which would translate into higher compensation. Thus, if motorists are killing their victims conditional on an accident, we would also expect to observe an increase in death ratio and a decrease (or smaller increase) in injury ratio in provinces with higher high health care prices. In an attempt to explore this conjecture, we estimate the following model:

$$Y_{gpt} = \beta_1 (A_g \times RTSL_t) + \beta_2 (A_g \times RTSL_t \times High_p) + \beta_3 High_p + \theta' X_{gpt} + \mu_g + \mu_p + \mu_t + \varepsilon_{gpt}, \quad (2)$$

[13] Sant (2015) documents several examples of potential hit-and-kill cases. Interested readers may refer to seleted videos on the phenomenon at https://www.youtube.com/watch?v=JhvwUo0M7W0 and https://www.youtube.com/watch?v=ORHlKWJuIss, retrieved 2 March 2017.

where $High_p$ denotes a dummy variable that takes a value of 1 if province p's pre-RTSL health care consumer price index was above the average across all provinces and a value of 0 otherwise.

Table 3 reports the results from the interaction analysis. As can be seen from the table, the estimated β_1 are similar to those from Table 2. Conversely, the estimated β_2 tend to be statistically insignificant at the 5% level across all outcome variables and specifications. For the death ratio outcome, the estimated β_2 is negative and marginally statistically significant in Columns (1) to (3), which goes in the opposite direction of what one would expect in the presence of hit-and-kill incentives. The estimates remain negative although they are not statistically significant in the logarithmic specification in Columns (4) to (6). Furthermore, for the injury ratio outcome, the estimated β_2 is positive although statistically insignificant at the 5% level. Thus, we have no evidence that the introduction of the RTSL may have interacted with health care prices and further encouraged motorists to kill the victims that they hit in regions with higher health care prices.[14]

Finally, in the presence of hit-and-kill incentives, one would expect the death ratio increase to be driven by deaths in accidents involving vulnerable road users such as pedestrians or cyclists. Figure 4 illustrates the trends in the number and ratio of deaths in accidents involving different types of road users.[15] From the top panels, the number of deaths in accidents involving bicycles and pedestrians seem to have decreased after the RTSL. Conversely, from the bottom panels, no clear pattern emerges in terms of the ratio of deaths to accidents involving bicycles or pedestrians. Meanwhile, the ratio of deaths to accidents involving motor vehicles seem to have increased sharply after 2003, suggesting that the increase in deadliness of accidents may be attributed to accidents involving motor vehicles but not to accidents involving vulnerable road users.

Although the anecdotal accounts and videos are compelling, our results suggest that the hit-and-kill phenomenon may not be prevalent enough to generate the sharp increase in death ratio that we see in the data. Altogether, while hit-and-kill incentives may exist on an anecdotal basis, such channel does not seem to drive the sharp patterns observed in the data.

[14]Regions with high health care prices could also be associated with better quality of care [shortage of medical staff], which may imply lower [higher] death rates. We control for number of hospital beds and number of medical personnel per 10,000 persons, which may proxy for quality of care and shortage of medical staff in Columns (2)-(3) and (5)-(6). There is also the possibility that regions with high health care prices could be associated with higher victim side moral hazard, where victims are more likely to fake accidents and claim to be injured for the sake of receiving compensation. Altogether, we find no evidence that the introduction of the RTSL may have interacted with health care prices to encourage victim side moral hazard from our accidents per 10k, injuries per 10k, and injury ratio regressions.

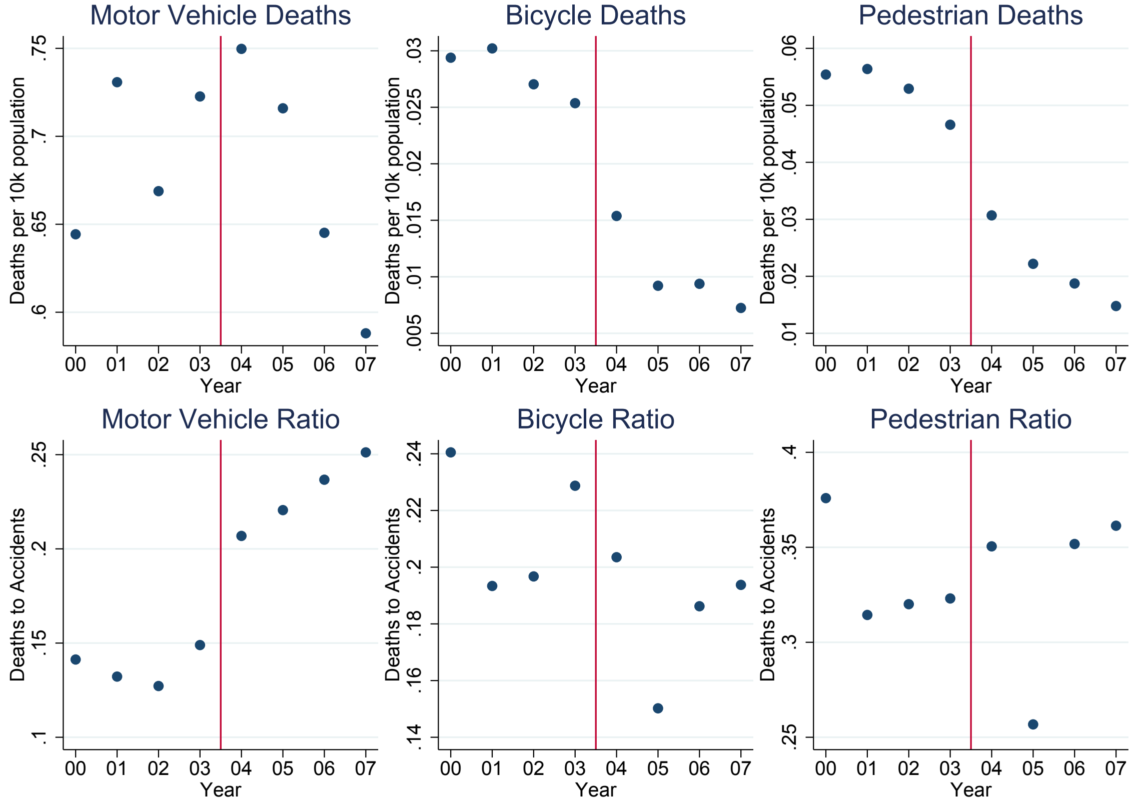
[15]Data on the types of road users is available only at the national level.

Table 3: Interaction Analysis Using Pre-RTSL Health Care Prices

	Levels			Logarithm		
	(1)	(2)	(3)	(4)	(5)	(6)
Accidents per 10k						
$A_g \times RTSL_t$	-2.542**	-3.216**	-2.844**	-0.395**	-0.450**	-0.420**
	(0.620)	(0.615)	(0.584)	(0.083)	(0.082)	(0.086)
$A_g \times RTSL_t \times High_p$	-0.993	-1.989†	-2.464†	-0.120	-0.139	-0.215
	(0.653)	(1.071)	(1.584)	(0.119)	(0.115)	(0.138)
R-squared	0.59	0.76	0.79	0.78	0.87	0.89
Deaths per 10k						
$A_g \times RTSL_t$	-0.075	-0.130**	-0.126*	-0.041	-0.070**	-0.069**
	(0.048)	(0.044)	(0.048)	(0.025)	(0.023)	(0.025)
$A_g \times RTSL_t \times High_p$	-0.004	-0.096†	-0.103†	0.005	-0.044	-0.050
	(0.073)	(0.050)	(0.055)	(0.040)	(0.026)	(0.030)
R-squared	0.88	0.95	0.96	0.93	0.97	0.97
Injuries per 10k						
$A_g \times RTSL_t$	-0.824*	-1.227**	-1.175**	-0.191*	-0.259**	-0.258**
	(0.397)	(0.392)	(0.416)	(0.072)	(0.067)	(0.070)
$A_g \times RTSL_t \times High_p$	0.113	-0.647	-0.657	0.099	-0.040	-0.040
	(0.522)	(0.393)	(0.433)	(0.102)	(0.071)	(0.080)
R-squared	0.77	0.88	0.90	0.93	0.96	0.97
Death ratio						
$A_g \times RTSL_t$	0.129**	0.126**	0.130**	0.101**	0.098**	0.101**
	(0.025)	(0.026)	(0.029)	(0.017)	(0.019)	(0.021)
$A_g \times RTSL_t \times High_p$	-0.055†	-0.042†	-0.048†	-0.037	-0.026	-0.030
	(0.031)	(0.025)	(0.028)	(0.023)	(0.017)	(0.020)
R-squared	0.86	0.91	0.92	0.88	0.92	0.93
Injury ratio						
$A_g \times RTSL_t$	0.334**	0.309**	0.301**	0.179**	0.167**	0.162**
	(0.033)	(0.049)	(0.053)	(0.018)	(0.028)	(0.031)
$A_g \times RTSL_t \times High_p$	0.005	0.028	0.032	0.007	0.019	0.022
	(0.040)	(0.035)	(0.043)	(0.019)	(0.019)	(0.024)
R-squared	0.96	0.97	0.97	0.97	0.98	0.98
N	480	480	480	480	480	480
Controls						
Covariates		x	x		x	x
Province trend			x			x
Year FE	x	x	x	x	x	x
Province FE	x	x	x	x	x	x

Note: Standard errors clustered at the province level. $^{\dagger}\ p < .1, ^{*}\ p < .05, ^{**}\ p < .01$.

Figure 4: Road Users Involved in Road Traffic Accident Deaths in China



Note: The top panels illustrate the number of deaths in accidents involving different types of road users per 10,000 persons. The bottom panels illustrate the ratio of deaths to accidents involving different types of road users. The vertical line illustrates when the RTSL was enacted.

4.3 Differential Death Ceilings Reporting Incentives?

As with most of the literature on road accidents and casualties, our study is not immune to reporting issues.[16] Below we address the potential issues associated reporting incentives of public officials due to the presence of death ceilings, and in Section 5.3, we analyse the potential issues associated with motorists' reporting incentives after the passage of the RTSL.

As described above, several provinces imposed "no safety, no promotion" rules that made

[16]For example, Alcorn (2011) posits that fatalities reported by the Ministry of Public Security (MPS) are lower relative to fatalites reported by the Ministry of Health (MOH) and attributes this discrepancy to under-reporting by local officials under MPS, whose promotions may be tied to meeting death ceilings. However, Alcorn (2011) does not clarify that the MPS and MOH define accident fatalities differently: The MPS [MOH] defines road traffic fatalities as deaths occuring with seven [thirty] days of an accident, which may also account for the discrepancies in reported fatalities. While there may be concerns that the RTSL may have changed reporting incentives, we note that this does not seem to be the case. In particular, the number of fatalities reported by the MPS as a proportion of those reported by the MOH are similar before and after the introduction of the RTSL: For 2003 and 2005 respectively, the MPS estimated 104,372 and 98,738 fatalities while the MOH estimated 220,000 and 206,000 fatalities (World Bank, 2008b).

promotion of local government officials contingent on meeting death ceilings. During our period of interest, four provinces introduced "no safety, no promotion" rules: Guangdong in 2005, Guizhou in 2006 and Ningxia in 2006, and Heilongjiang in 2007.[17] As can be seen from Figure 1, the changes observed in road accidents and casualties seem to occur closely to the passage of the RTSL. In addition, from Appendix Figure A3, the decline in road deaths was present across all provinces irrespective of the introduction of the "no safety, no promotion" rules, suggesting that the RTSL was the most relevant factor driving the decline in road accidents and casualties.

Nevertheless, one concern is that provinces with the "no safety, no promotion" rule may have experienced under-reporting of accidental fatalities. In particular, Fisman and Wang (2017) argue that such laws may encourage officials to under-report deaths although they cannot rule out that such laws may have also encouraged better safety practice. We investigate whether our results could be driven by different reporting incentives on road and fire deaths due to the death ceilings. We exploit province and time variation in the introduction of the death ceilings to control for potentially different reporting incentives according to the accident type and see whether this affects our findings on the effects of the RTSL on road accidents and casualties. We thus re-estimate Model (1) by adding a $Ceiling_{pt}$ dummy variable that takes a value of 1 for provinces and years in which the "no safety, no promotion" rules were in place, and a value of 0 otherwise, and an interaction term $A_g \times Ceiling_{pt}$ that captures the potentially differential effects on road and fire accidents.

Table 4 reports the effects of the RTSL that account for potential changes in reporting rates due to the death ceilings. As before, we report results controlling for province and year fixed effects in Columns (1) and (4), additionally controlling for the time and group varying province level variables in Columns (2) and (5), and further controlling for province specific trends in Columns (3) and (6). As can be seen from Table 4, the estimated effects of the RTSL are quantitatively very similar to the results reported in Table 2, which suggests that the imposition of death ceilings is unlikely to be the driving force behind our results.[18]

As further sensitivity checks, we also re-estimated Model (1) by (i) dropping the four provinces affected by the death ceilings, Guandong, Guizhou, Ningxia and Heilongjiang, from the sample,

[17] As of 2012, 16 more provinces had imposed the "no safety, no promotion" rules while the remaining provinces did not (Fisman and Wang, 2017, Table A1).

[18] There seems to be some evidence consistent with potential substitution in fatalities reporting across road and fire accidents: Death ceilings are associated with a decrease in reported deaths for road accidents but an increase in the reported deaths for fire accidents in Columns (2), (3), (5), and (6). This seems consistent with Fisman and Wang (2017), who argue that local officials may have an incentive to switch deaths reports across accident categories in order to meet the death ceilings. Nevertheless, the effects of the death ceilings are always statistically insignificant at the 5% level for the death ratio outcomes.

Table 4: Accounting for Differential Death Ceiling Reporting Incentives

	Levels			Logarithm		
	(1)	(2)	(3)	(4)	(5)	(6)
Accidents per 10k						
$A_g \times RTSL_t$	-3.080**	-4.025**	-3.819**	-0.468**	-0.510**	-0.508**
	(0.755)	(0.919)	(0.854)	(0.063)	(0.087)	(0.087)
$A_g \times Ceiling_{pt}$	0.624	0.433	0.037	0.184	0.106	0.077
	(1.619)	(2.012)	(1.714)	(0.366)	(0.236)	(0.220)
$Ceiling_{pt}$	-0.510	-0.087	0.352	-0.115	-0.020	-0.046
	(0.922)	(0.830)	(1.205)	(0.187)	(0.151)	(0.172)
R-squared	0.59	0.75	0.78	0.78	0.87	0.89
Deaths per 10k						
$A_g \times RTSL_t$	-0.076*	-0.157**	-0.156**	-0.038*	-0.082**	-0.083**
	(0.031)	(0.040)	(0.042)	(0.016)	(0.020)	(0.021)
$A_g \times Ceiling_{pt}$	-0.014	-0.257*	-0.252*	-0.009	-0.132*	-0.133*
	(0.146)	(0.112)	(0.120)	(0.087)	(0.050)	(0.056)
$Ceiling_{pt}$	-0.073	0.105*	0.123†	-0.028	0.062*	0.066†
	(0.119)	(0.049)	(0.068)	(0.062)	(0.027)	(0.035)
R-squared	0.88	0.95	0.96	0.93	0.97	0.97
Injuries per 10k						
$A_g \times RTSL_t$	-0.839**	-1.477**	-1.427**	-0.150**	-0.275**	-0.273**
	(0.282)	(0.401)	(0.409)	(0.047)	(0.058)	(0.061)
$A_g \times Ceiling_{pt}$	1.077	-0.209	-0.175	0.134	-0.018	-0.015
	(1.437)	(0.682)	(0.613)	(0.322)	(0.094)	(0.096)
$Ceiling_{pt}$	-0.759	0.196	0.151	-0.047	0.087	0.016
	(0.904)	(0.379)	(0.385)	(0.183)	(0.054)	(0.064)
R-squared	0.78	0.88	0.89	0.93	0.96	0.97
Death ratio						
$A_g \times RTSL_t$	0.102**	0.112**	0.114**	0.083**	0.090**	0.091**
	(0.012)	(0.018)	(0.019)	(0.009)	(0.013)	(0.014)
$A_g \times Ceiling_{pt}$	-0.002	-0.052	-0.063	-0.008	-0.044	-0.051
	(0.078)	(0.061)	(0.070)	(0.057)	(0.043)	(0.049)
$Ceiling_{pt}$	-0.013	0.013	0.027	-0.008	0.013	0.023
	(0.026)	(0.026)	(0.029)	(0.019)	(0.019)	(0.021)
R-squared	0.85	0.90	0.92	0.88	0.92	0.93
Injury ratio						
$A_g \times RTSL_t$	0.327**	0.317**	0.310**	0.178**	0.174**	0.170**
	(0.026)	(0.045)	(0.048)	(0.014)	(0.026)	(0.028)
$A_g \times Ceiling_{pt}$	0.129*	0.048	0.067	0.060**	0.016	0.026
	(0.049)	(0.077)	(0.088)	(0.021)	(0.041)	(0.046)
$Ceiling_{pt}$	-0.058**	0.020	-0.048	-0.028*	0.013	-0.022
	(0.020)	(0.042)	(0.057)	(0.011)	(0.023)	(0.032)
R-squared	0.96	0.97	0.97	0.97	0.98	0.98

Note: Standard errors clustered at the province level. † $p < .1$, * $p < .05$, ** $p < .01$.

and (ii) limiting the sample to years 2002 to 2005. The results are reported in Appendix Tables A1 and A2. Once again, the estimated effects of the RTSL on road accidents and casualties were similar to those reported in Table 2.

4.4 Further Validation Checks

As further validation check on our common trends assumption between fire and road accidents, we include interaction terms between year dummies and accident group, A_g, in our analysis. We estimate the following model:

$$Y_{gpt} = \sum_{t=2001}^{2007} \beta_t \left(A_g \times Year_t\right) + \theta' X_{gpt} + \mu_g + \mu_p + \mu_t + \varepsilon_{gpt}, \tag{3}$$

where $Year_t$ denote year dummies for years 2001 to 2007 (with 2000 as the reference base year), μ_t is a vector of year dummies inclusive of $Year_t$, and the remaining variables are defined as before.

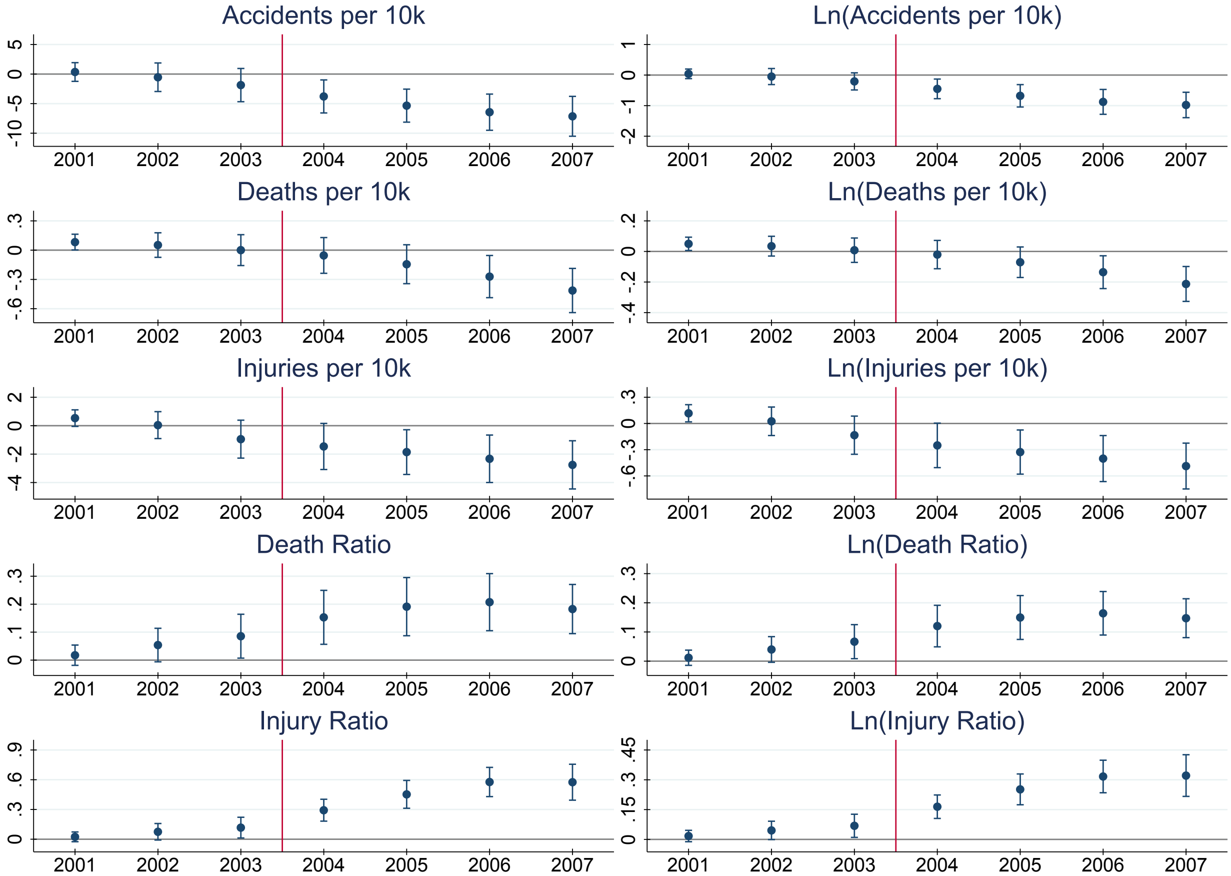
Figure 5 reports the β_t coefficients and 95% confidence intervals from the full specification for Model (3), that is, including controls for province and year fixed effects, time and group varying province level variables, and province specific trends. As can be seen from the Figure, the estimates seem to indicate that most effects coincided closely with the timing of the RTSL, with small and generally statistically insignificant effects at the 5% level prior to 2004. While there seem to have been some small and statistically significant effects in 2003 for death ratio and injury ratio, the effects for the number of accidents, deaths and injuries are not statistically significant in 2003. As the RTSL was enacted in October 2003 and implemented in May 2004, it is possible that those relatively small effects were generated by the enactment of the law itself while the actual implementation generated larger effects.

We perform a simple placebo test to further check the validity of our DID strategy. In particular, we use data from years 1992 to 1995 and posit that a reform took place in 1994 such that we redefine $RTSL_t$ as a dummy variable taking a value of 1 for years 1994 onwards, and a value of 0 otherwise. As the corresponding China Statistical Yearbooks only contain national level accidents data, we estimate a parsimonous version of Model (1) at the national level:

$$Y_{gt} = \beta \left(A_g \times RTSL_t\right) + \mu_g + \mu_t + \varepsilon_{gt}. \tag{4}$$

For the sake of comparability, we also estimate Model (4) using national level data from years

Figure 5: Group-Year Interactions



Note: β_t coefficients from Model (3) and 95% confidence are reported. Controls include province and year fixed effects, time and group varying province level variables, and province specific trends. The left [right] panels report results when the outcome variable is specified in levels [logarithm], $Y_{gpt} = y_{gpt}$ $[Y_{gpt} = ln(y_{gpt}+1)]$. The vertical line illustrates when the RTSL was enacted.

2002 to 2005 with $RTSL_t$ defined as in Model (1).

Table 5 reports the estimated β from the Model (4). For years 1992 to 1995, we find no statistically significant effect of the placebo reform at the 5% level for any of the outcome variables. As expected, with only national level data for 8 year-accident type observations, the effects of the RTSL are estimated less precisely. Nevertheless, for years 2002 to 2005, the estimated β are qualitatively similar to the estimates from Table 2, with statistically significant effect at the 10% level on the number of accidents and statistically significant effects at the 5% level on the death ratio and injury ratio outcomes. This gives us further confidence in our DID strategy.

Some potential issues may remain in terms of other possible changes driven by the RTSL. First, motorists may substitute fire/property insurance for road insurance since the RTSL made

Table 5: Placebo Test

	Levels		Logarithm	
	1992-1995	2002-2005	1992-1995	2002-2005
Accidents per 10k	0.202	-1.765†	0.070	-0.296*
	(0.089)	(0.451)	(0.034)	(0.066)
Deaths per 10k	0.051	-0.041	0.032	-0.023
	(0.056)	(0.041)	(0.017)	(0.023)
Injuries per 10k	0.070	-0.449	0.034	-0.088
	(0.046)	(0.279)	(0.025)	(0.054)
Death ratio	-0.008	0.063*	-0.007	0.053*
	(0.008)	(0.009)	(0.008)	(0.008)
Injury ratio	-0.008	0.254*	-0.001	0.137*
	(0.055)	(0.059)	(0.044)	(0.030)

Note: Robust standard errors in parentheses. † $p < .1$, * $p < .05$, ** $p < .01$.

third party liability auto insurance compulsory. For example, Koeniger (2004) shows that agents with higher labour income risk spend more on car insurance in the UK, thereby suggesting that the level of risk in one domain may affect the purchase of insurance in another. If people indeed substitute fire insurance for auto insurance, then this may decrease the moral hazard incentives associated with fires, and thus reduce fire accidents and casualties, which may attenuate the estimated effects of the RTSL on road accidents and casualties. Regardless, in our context, since fire insurance is not compulsory and property insurance markets are underdeveloped in China, very few people take up such insurance in the first place, such that there are limited substitution possibilities between insurance for road and fire accidents. While the property insurance market has been growing rapidly, only 5% of property in China is insured, with most of insurance coverage falling on commercial and industrial users (World Bank, 2008a). Thus, such insurance substitution possibilities may not be salient in our context. Second, motorists may have changed their road accident reporting behavior due to the RTSL. We address this issue in the next section.

5 Theoretical Insights

This section provides some theoretical insights on the potential mechanisms that may drive a decrease in the number of accidents and casualties coupled with an increase in the ratio of casualties to accidents. We focus on casualties as measured by death but note that the model would also be applicable to injuries. In Section 5.1, we present a parsimonious model of driving effort and show that, even if all motorists drive more carefully after an increase in the strictness of the law, the death ratio may still increase if accidents caused by safer drivers decline by more than those caused by riskier drivers. We discuss alternative mechanisms in Section 5.2 and extend the model to incorporate motorists' reporting behavior in Section 5.3.

5.1 A Model of Driving Effort

We present a model where drivers are heterogeneous in their riskiness in terms of the severity of accidents that they cause. For example, drunk drivers tend to be at higher risk of causing fatal accidents than sober drivers due to their slower perception-reaction times. Given their riskiness level, drivers choose driving effort, which influences their probability of causing an accident. We show that if motorists adjust their effort in response to an increase in the strictness of the law, such that the probability of causing an accident decreases by more for safer drivers than for riskier drivers, then we may get a decrease in the number of accidents and deaths coupled with an increase in the death ratio.

Heterogeneous motorists Suppose that motorists are heterogeneous in driving type $\theta \in [0,1]$. Let $F(\theta)$ denote the cumulative distribution of θ. We interpret θ as the riskiness of the driver, where higher θ indicates riskier drivers, such as those with slower perception-reaction times.

Driving effort Let $e \in \mathbb{R}^+$ denote driving effort, where higher e denotes higher effort. e could be interpreted as the level of attention exerted by the motorist or as investment in safety such as wearing seat belts. Denote $p(e,\theta)$ the probability that a driver of type θ gets into an accident given effort level e. We assume that $p(.)$ is decreasing and convex in e: $p_e(.) < 0$, $p_{ee}(.) > 0$.

Damages Let $x \in \mathbb{R}^+$ denote the amount of damages caused (e.g., car damage, injury, death) when a driver gets into an accident. The more serious an accident, the higher x is. Denote $G(x|\theta)$ as the cumulative distribution of damages that may occur when a motorist of type θ gets into an accident. Assume that $G(x|\theta)$ is decreasing in θ, that is, riskier drivers have more severe accidents.

Denote the expected damages of an accident as $\mathbb{E}(x|\theta) = \int_x x dG(x|\theta)$. Let x_D be the threshold level of damages above which an accident is fatal. The probability that an accident is fatal for a motorist of type θ is given by $\gamma(x_D|\theta) := 1 - G(x_D|\theta)$, which also reflects the death ratio for such a motorist. Since $G(x|\theta)$ is decreasing in θ, the death ratio must increase in θ. Thus, the accidents involving riskier drivers are more likely to be be fatal.

Motorist Problem Let $\phi \in \mathbb{R}^{++}$ be an enforcement parameter capturing the strictness of the law. For example, a higher fine or punishment would be captured by a higher ϕ. Given a level of enforcement, each motorist chooses effort so as to minimize the expected costs of an accident:

$$\underset{e \geq 0}{Min}\, \phi p(e,\theta)\mathbb{E}(x|\theta) + e. \tag{5}$$

The expected costs of an accident are made up of the sum of two terms: (i) the expected damages weighted by the enforcement parameter and by the probability of causing an accident, and (ii) the cost of effort. Next, we show that all motorists drive more carefully after the reform.

Lemma 1. *Higher enforcement increases effort among all driver types:*

$$\forall \theta, \quad \frac{\partial e(\theta)}{\partial \phi} > 0.$$

Proof. See Appendix B.1. □

The proof is derived from the first order condition to the objective function in (5). The intuition is straightforward: The higher the enforcement parameter, the higher the expected costs of causing an accident. Each motorist will, therefore, have an incentive to exert higher effort in an attempt to counterbalance the higher expected accident costs. As a result, there will be a decrease in the probability that each motorist gets into an accident, which leads to a decrease in the number of accidents and casualties.

We next examine what happens to the population death ratio. Note that since $\gamma(x_D|\theta)$ does not depend on e, the death ratio is invariant to driver effort for a given θ. We show that even if all motorists exert higher effort, and $\gamma(x_D|\theta)$ is invariant to effort, the average deadliness of accidents may still increase in response to an increase in ϕ. This is based on the monotonicity of two equilibrium objects in motorists' type: First, the change in the equilibrium probability of accidents with respect to the reform, and second, the equilibrium probability of an accident.

Define the population death to accident ratio as

$$r(\phi) = \frac{\int_0^1 \gamma(x_D|\theta)\, p(e(\theta),\theta)\, dF(\theta)}{\int_0^1 p(e(\theta),\theta)\, dF(\theta)}, \tag{6}$$

where the denominator denotes the total number of accidents and the numerator denotes the total number of deaths. Note that this ratio does depend on driver effort as it also depends on the probability of causing an accident.

We further define the following conditions:

Condition 1. $\frac{\partial p(e(\theta),\theta)}{\partial \phi}$ *is increasing in* θ.

Condition 2. $p(e(\theta);\theta)$ *is increasing in* θ.

From Lemma 1, an increase in ϕ leads to an increase in effort $e(\theta)$ and therefore, a decrease in the probability of an accident $p(e(\theta),\theta)$ for all motorists. Condition 1 states that the decline in the equilibrium probability of an accident following an increase in ϕ is greater for safer drivers (lower θ) than for riskier drivers (higher θ). Condition 2 implies that the equilibrium probability of accident for riskier drivers is greater than that of safer drivers. Note that Conditions 1 and 2 are both restrictions on equilibrium objects since $e(\theta)$ is an equilibrium variable. These conditions are easily satisfied under reasonable functional forms such as exponential distribution for $G(x|\theta)$ and power function for $p(e,\theta)$. See Appendix B.2 for such an illustration.

We next explore the implications of the two conditions for the ratio of deaths to accidents.

Proposition 1. *If Conditions 1 and 2 are satisfied [reversed], then an increase in enforcement will lead to an increase [a decrease] in the death to accident ratio.*

Proof. See Appendix B.3. □

Proposition 1 characterises how, in theory, the death to accident ratio may increase or decrease following an increase in enforcement. The intuition behind this result is simple. After the reform (an increase in ϕ), all drivers increase their effort. However, the increase in the effort of the safer drivers leads to a greater decrease in the probability of an accident compared to riskier drivers. Since the distribution of damages conditional on an accident $G(x|\theta)$ remains unaffected, the drop in the probability of accidents disproportionally reduces the less severe accidents relative to the severe accidents. Therefore, the population death to accident ratio increases. This implies that the proportion of severe accidents can increase quite naturally following a road safety reform if the decrease in the probability of getting into an accident is greater for safer drivers than for riskier drivers. Conversely, when Conditions 1 and 2 are reversed, the reverse happens: The decrease in accidents causing casualties is greater than the decrease in safer accidents, and consequently, the death to accident ratio decreases.

Note that regardless of how the death ratio changes, the effort exerted by all drivers increase after the reform. In this sense, greater enforcement successfully leads to everyone driving more carefully. However, the effect of an increase in effort on the deadliness of accidents is ambiguous when there are heterogeneous responses by motorists.

The presence of some heterogeneity is necessary for such results. To see this, note that in the case of homogeneous drivers, the distribution of damages would be the same across all drivers, $G(x)$, and the equilibrium probability of an accident would also be the same for a given effort level, $p(e)$. This model would be a special case of the motorist's problem defined in (5) such that we would still obtain an increase in driving effort following an increase in ϕ, thereby leading to a decrease in the number of accidents and casualties. However, in the case of homogeneous drivers, the death ratio will remain constant. In particular, the death ratio corresponding to (6) is now simply given by $\gamma(x_D) = 1 - G(x_D)$, which coincides with the probability that an accident is fatal for a motorist.

Our results are consistent with Zhang et al. (2014), who document that the decrease in the number of speeding and drunk driving related injuries was not proportional to the corresponding decrease in road accidents related injuries after the passage of the RTSL. In particular, speeding and drunk driving related injuries decreased by 22% whereas road accident related injuries decreased by 47% from 2004 to 2010. This is also consistent with Ruhm (1996), who finds that alcohol-control policies have little impacts on road fatalities. Such findings map into our model if riskier drivers are mainly responsible for speeding and drunk driving accidents. In this case, stricter policies that target speed limits enforcement or alcohol consumption may help decrease casualties caused by such drivers even further.

Note that our model is extendable in several ways. For instance, we could allow the distribution of damages to depend on both effort and driver type. Moreover, the cost of driving effort could be convex in effort rather than linear. Such cost could also depend on driver type. We present a generalized model in Appendix B.4 and show how an increase in ϕ may still lead to a decrease in the number of accidents and casualties coupled with an increase in the death to accident ratio.

5.2 Alternative Mechanisms

We now discuss alternative, possibly overlapping, mechanisms that could also drive a decrease in accidents and casualties but an increase in the ratio of casualties to accidents.

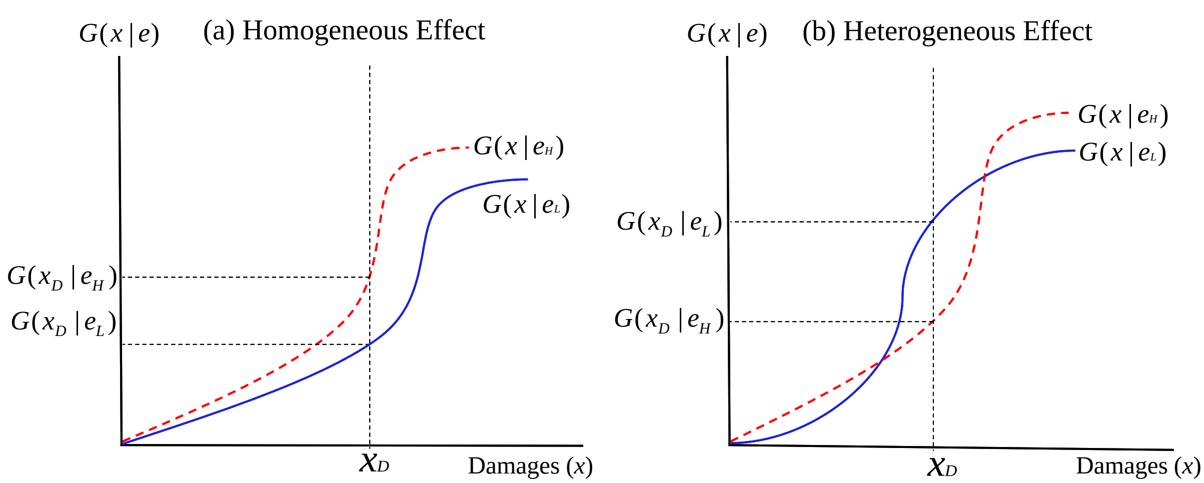
Driving Externalities We have shown how an increase in driving effort could be consistent with both a decrease in the number of accidents and casualties and an increase in the death ratio, in a relatively parsimonous model. This does not rule out the possibility that safer drivers may be driving more carefully while riskier drivers may be driving more recklessly. In particular, an alternative mechanism that may be consistent with the empirical findings, could be one with driving externalities, where drivers respond strategically to the effort choice of other drivers. For example, riskier drivers may drive more recklessly in equilibrium, as a result of an increase in driving effort by safer drivers. Nevertheless, such mechanism would also rely on the presence of driving heterogeneity, where the overall decline in accidents by safer drivers outweigh the recklessness of riskier drivers.

Driver Composition An increase in the strictness of the law also makes driving more costly. For example, as documented in Section 2, the RTSL subjected motor vehicles to regular safety technical inspections and made third-party liability insurance compulsory. Thus, there may have been a change in the composition of motorists on the road. In terms of our model in Section 5.1, this would imply that the distribution of drivers on the road, $F(\theta)$, may also change. In particular, even if the RTSL does not induce any change in effort on the part of motorists, we may still observe a decrease in the number of accidents and casualties but an increase in the casualties to accidents ratio. In particular, this may occur if the composition of drivers changed after the reform, such that there is a drop in the proportion of safer drivers on the road, or equivalently, an increase in the proportion of riskier drivers on the road.

Passenger Composition An increase in cost of driving could also increase the number of passengers in vehicles as they may be unwilling to drive themselves. Routley et al. (2008) documented an increase in the number of front (but not back) passengers in vehicles in two cities in China, Nanjing and Zhoushan, from 2005 to 2007. Furthermore, they also document a decrease in the proportion of passengers wearing seatbelts over the same period. This is consistent with Peltzman (1975) who argued that motorists may become more reckless in the light of improved vehicle safety. In our case, the more reckless ones could have also been the passengers. Thus, changes in the composition of passengers may have also increased the severity of damages conditional on an accident after the RTSL.

Damage Distribution The presence heterogeneity can also be incorporated in a model with homogeneous drivers but with effort affecting the distribution of damages in a heterogeneous fashion. Such a model can also generate a decrease in accidents and casualties coupled with an increase in death ratio. To see this, assume that drivers are homogeneous and that the distribution of damages depends on effort, $G(x|e)$. Let the size of the population be n, and let an increase in ϕ cause an increase in effort from e_L to e_H such that the probability of an accident occuring decreases. If a reform leads to an increase in effort and such increase reduces the cumulative probability distribution of damages in a first order stochastic dominance sense, then the death ratio $\gamma(x_D|e) = 1 - G(x_D|e)$ will decrease in e. Such a situation is illustrated in Figure 6(a), where x_D is the death threshold in the distribution of damages. In this case, the improved driving effort will decrease the number of accidents $np(e)$ and the number of deaths $np(e)\gamma(x_D|e)$, as well as the death to accident ratio $\gamma(x_D|e)$. Thus, a model with homogeneous drivers and homogeneous effect of effort on the distribution of damages is not consistent with the patterns observed in the data.

Figure 6: Effect of Effort on the Distribution of Damages



Note: $G(x|e_L)$ illustrates the cumulative distribution of damages that occurs prior to the RTSL. Suppose that the RTSL encouraged drives to drive more carefully and exert higher effort, thereby resulting in distribution $G(x|e_H)$. If the distribution of damages changes in a first order stochastic dominance sense [heterogeneously], then we may observe a decrease [an increase] in the probability of death conditional on an accident: $\gamma(x_D|e_H) = 1 - G(x_D|e_H) < 1 - G(x_D|e_L) = \gamma(x_D|e_L)$ $[\gamma(x_D|e_H) > \gamma(x_D|e_L)]$.

Conversely, it is possible that the effect of an increase in effort has a heterogeneous effect on different parts of the distribution $G(x|e)$. We can see an illustration in Figure 6(b), where an increase in effort leads to an increase the likelihood of death conditional on an accident. In this case, it is possible that a reform decreases the number of accidents $np(e)$ but increases the death to accident ratio $\gamma(x_D|e)$. If the decrease in probability of accidents outweights the increase in the death ratio, then the number of deaths $np(e)\gamma(x_D|e)$ will also decrease. Thus, some sort of heterogeneity, such as in driver types or in the effect of effort on the resulting distribution of damages, is needed to be consistent with the fact that an increase in ϕ leads to a decrease in the number of accidents and deaths but an increase in the death to accident ratio.

5.3 Reporting Incentives

In Section 4, our DID strategy helps mitigate issues associated with reporting incentive trends that are common across road and fire accidents, while controlling for death ceilings helps address public officials' reporting incentives. We now address potential changes in motorists' reporting incentives after the RTSL and discuss the implications for our empirical estimates. We extend the model presented in Section 5.1 to consider the reporting incentives of motorists after an increase in the strictness of the law. We show that an increase in the strictness of the law could encourage accident reporting as the expected costs of a motorist caught after fleeing the scene of an accident increases, such that the accidents estimates may be attenuated. Furthermore, if less [more] severe accidents get under-reported, then the reported death ratio could also decrease [increase] such that the death ratio estimates may represent lower [upper] bounds in magnitude.

Two-stage problem The motorist's problem now takes the form of a two-stage process:

Stage 1: The motorist choses driving effort, e.

State 2: Conditional on an accident, the motorist chooses whether to report it or not.

The motorist's problem is solved backwards starting from stage 2.

Stage 2 When an accident occurs with a corresponding damage, x, the motorist decides whether to report the accident or not. If the motorist reports the accident, he incurs a cost of x. If the motorist does not report the accident (flees), then he is caught with probability $\pi(x)$ and made to pay a fine of $\tau(x)$. If the fleeing motorist is not caught, then he incurs zero cost. Thus, the expected cost of not reporting an accident is $\pi(x)\tau(x)$. We assume that $\pi(x)\tau(x)$ is increasing in x, such that the expected cost of a fleeing motorist increases in the severity of damages. We also assume that $\pi(0)\tau(0) = 0$, such that a motorist who does not cause any damage or personal injury faces zero expected cost.[19] A motorist thus reports the accident as long as the cost of reporting the accident is lower than the expected cost of not reporting the accident:

$$x \leq \pi(x)\tau(x).$$

Stage 1 The motorist chooses effort to minimize the expected costs of an accident:

$$\underset{e\geq 0}{Min}\ \phi p(e,\theta)\mathbb{E}(min\{x,\pi(x)\tau(x)\}|\theta)+e.$$

This is analogous to the motorist's problem defined in (5), except that the motorist now factors in the reporting choice. Note that since $\mathbb{E}(min\{x,\pi(x)\tau(x)\}|\theta)$ is increasing in θ, the results from Lemma 1 and Proposition 1 still hold in this extended model. In particular, an increase in ϕ encourages all motorists to improve driving effort while the actual death ratio will increase if there is a greater decrease in the probability of an accident for safer drivers than for riskier drivers.

We now address issues related to accident reporting after an increase in the strictness of the law in terms of an increase in $\pi(.)\tau(.)$. As documented in Section 2, motorists who flee away from an accident are automatically liable for an accident, in addition to having to pay a fine and having their driving license revoked indefinitely, while witnesses who report the accident are rewarded. In addition, from Table 1, government expenditure on public security per capita nearly doubled after the RTSL, suggesting that enforcement improved. Thus, we expect both the probability of getting caught, $\pi(.)$, and the penalty for a fleeing motorist, $\tau(.)$, to be higher after the reform.

We first show that under-reporting can affect the less or more severe accidents depending on the shape of the expected cost faced by the a fleeing motorist. We then show how an increase in $\pi(.)\tau(.)$ affects accident reporting rates, and discuss the implications for our empirical estimates.

Lemma 2. *Assume that $\pi(x)\tau(x)$ is convex [concave] and $\underset{x\to\infty}{lim}\pi(x)\tau(x) > x$ $\left[\underset{x\to\infty}{lim}\pi(x)\tau(x) < x\right]$.*

1. There exists a threshold, x^*, defined as:

$$x^* = \pi(x^*)\tau(x^*),$$

such that drivers report accidents when $x \geq x^*[x \leq x^*]$, and do not report when $x < x^*$ $[x > x^*]$.

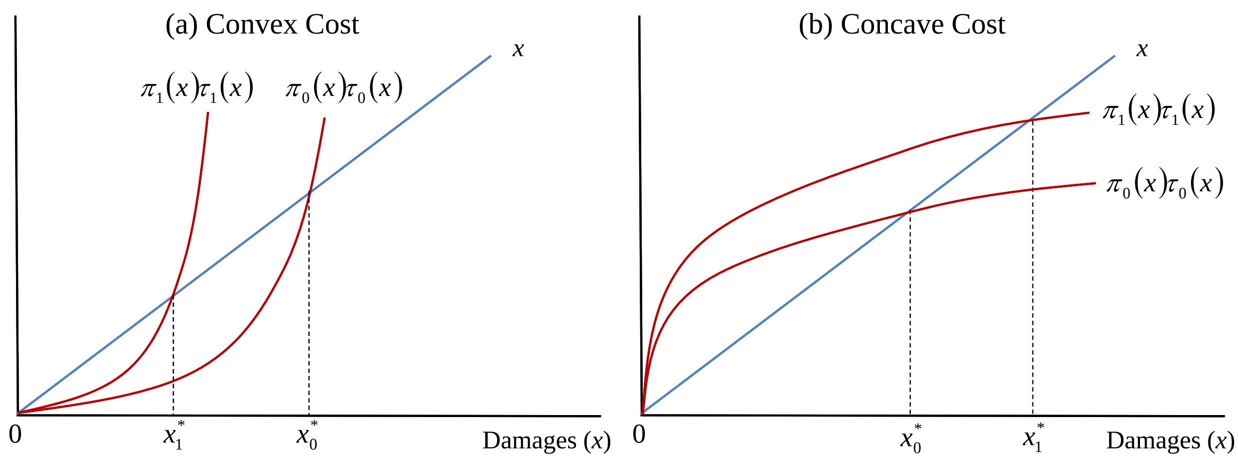
[19] The RTSL made it compulsory to report only accidents that result in personal injury or public damage. Hence, the cost associated with causing zero damage is assumed to be zero irrespective of reporting.

2. x^* decreases [increases] in response to an increase in the strictness of the law.

Proof. See Appendix B.5. □

Whether the less or more severe accidents are under-reported depends on the shape of the expected cost of fleeing as a function of the damage caused. Lemma 2 shows that if the expected cost of fleeing is convex [concave], then the less [more] severe accidents, that is, accidents below [above] some threshold level of damage, x^*, are not reported. An increase in $\pi(.)\,\tau(.)$ decreases [increases] the thresholds below [above] which accidents are not reported. Figure 7 provides an illustration, where subscripts 0 and 1 denote respectively, pre-reform and post-reform levels.

Figure 7: Reporting Thresholds



Note: With convex [concave] $\pi(x)\,\tau(x)$, motorists report accidents when $x \geq x^*$ $[x \leq x^*]$ and do not report accidents when $x < x^*$ $[x > x^*]$. x^* decreases [increases] when $\pi(.)\,\tau(.)$ increases.

Proposition 2. *If $\pi(x)\,\tau(x)$ is convex [concave], then the likelihood of reporting accidents and deaths cannot decrease while the reported death to accident ratio cannot increase [decrease] after an increase in the strictness of the law.*

Proof. See Appendix B.6. □

Proposition 2 shows that motorists will be more likely to report accidents and deaths when there is an increase in the strictness of the law. In particular, an increase in the probability that a fleeing motorist gets caught and/or an increase in the fine payable when caught increases the expected cost faced by a fleeing motorist, which discourages under-reporting. Thus, if the RTSL encouraged higher accident and death reporting rates, then our estimated effects of the reform on the number of accidents may be attenuated.

Conversely, the estimated effects on the death ratio may represent lower or upper bounds depending on what type of accident gets under-reported. Recall that x_D denotes the level of damages above which death occurs. From Figure 7(a) for convex $\pi(x)\tau(x)$, we can see that if $x_0^* \geq x_D$ so that only a portion of fatal accidents are reported prior to the reform, then the reported death ratio remains unchanged if $x_1^* \geq x_D$, or decreases if $x_1^* < x_D$. Conversely, if $x_0^* < x_D$ so that some non-fatal and all fatal accidents are reported prior to the reform, then the reported death ratio decreases. From Figure 7(b) for concave $\pi(x)\tau(x)$, we can see that if $x_0^* \leq x_D$ so that only a portion of non-fatal accidents are reported prior to the reform, then the reported death ratio remains unchanged if $x_1^* \leq x_D$, or increases if $x_1^* > x_D$. Conversely, if $x_0^* > x_D$ so that all non-fatal and some fatal accidents are reported prior to the reform, then the reported death ratio increases.

In a setting where less [more] severe accidents are under-reported, Proposition 2 shows that, holding the actual death ratio constant, the reform may cause the reported death ratio to decrease [increase]. In this case, the empirical estimates derived using the reported death ratio may represent lower [upper] bounds in magnitude. Given that fatal accidents are more likely to be reported than non-fatal ones, we thus expect our estimated effects of the reform to be attenuated if reporting rates indeed increased after the passage of the RTSL.

6 Conclusion

We estimate the effects of a major road safety reform undertaken by the Chinese government on road accident and casualties. The RTSL sought to promote traffic safety and attributed responsibility in accidents to motorists who could potentially face enormous costs of compensation for personal injury. Our results suggest that the reform led to a significant decrease in the number of accidents, deaths, and injuries on the road. To rule out potentially unobservable time effects, we show that the decline for these outcomes was greater than what was observed for the same period for fire accidents, deaths, and injuries, while also controlling for a hoard of accident type, province, and time varying covariates that may affect accidents and casualties.

We further show that although the RTSL led to a decline in the number of accidents and deaths, the ratio of deaths to accidents increased. Although the law has been criticised for potentially inducing motorists to kill the pedestrians that they hit in an accident, we find no evidence that supports such hit-and-kill incentives. Using a model with heterogeneous motorists, we show that even if the RTSL were successful in encouraging everyone to drive more carefully, the death ratio could still mechanically increase. In particular, if the decrease in the probability of getting into an accident is greater for safer drivers than for riskier drivers, less severe accidents would decrease by a larger proportion, such that the ratio of severe accidents to all accidents increases.

We note that our data may be subject to reporting issues, a limitation shared with most of the literature on road accidents and casualties. We address such reporting issues empirically and theoretically. In particular, our DID strategy helps difference out reporting incentive trends that are common across road and fire accidents, while controlling for death ceilings also helps in addressing public officials' reporting incentives under the "no safety, no promotion" rules. Since the RTSL increased the expected penalties imposed on fleeing motorists who get caught, we also expect accident reporting rates to have increased after the reform. In a setting where less severe accidents get under-reported, we show theoretically that our reform effect estimates would be attenuated.

Death to accident ratio is sometimes used as a measure of road safety. Anderson and Auffhammer (2014) use it to show that the likelihood of death conditional on there being an accident is increasing in the weight of the other vehicle. Li (2012) documents similar results using serious injury and death conditional on accident as the outcome variable. Similarly, DeAngelo and Hansen (2014) treat an increase in fatalities per fatal accident as implying that dangerous drivers drive more recklessly. Our results suggest that, in a setting where a road safety reform has heterogeneous responses, it may not be unnatural for the death ratio to rise even when the reform leads to an across the board improvement in driver effort. Hence, an overall increase in road safety following a reform, as seen in a decline in the number of accidents and casualties, is nonetheless consistent with an increase in the death to accident ratio. As such, one needs to be cautious when using death ratio as a measure of road safety.

Nevertheless, the use of casualty ratios as measures of success of road safety reforms would depend on the context of analysis. The death to accident ratio may be useful in settings where the decline in absolute number of deaths and accidents is not sufficiently informative. For instance, when analysing whether a reform induces hit-and-kill incentives, we would need to study the movement in the ratio of deaths to accidents. Furthermore, since serious accidents tend to get sensational news coverage, the government may care about reducing the death ratio. With micro-data on road accidents, we may be able to better understand the source of heterogeneity driving the more severe accidents. If the severe accidents are indeed being caused primarily by speeding or drunk drivers, then the focus of future policies may target speed limits enforcement or alcohol consumption. We leave such interesting considerations for future research.

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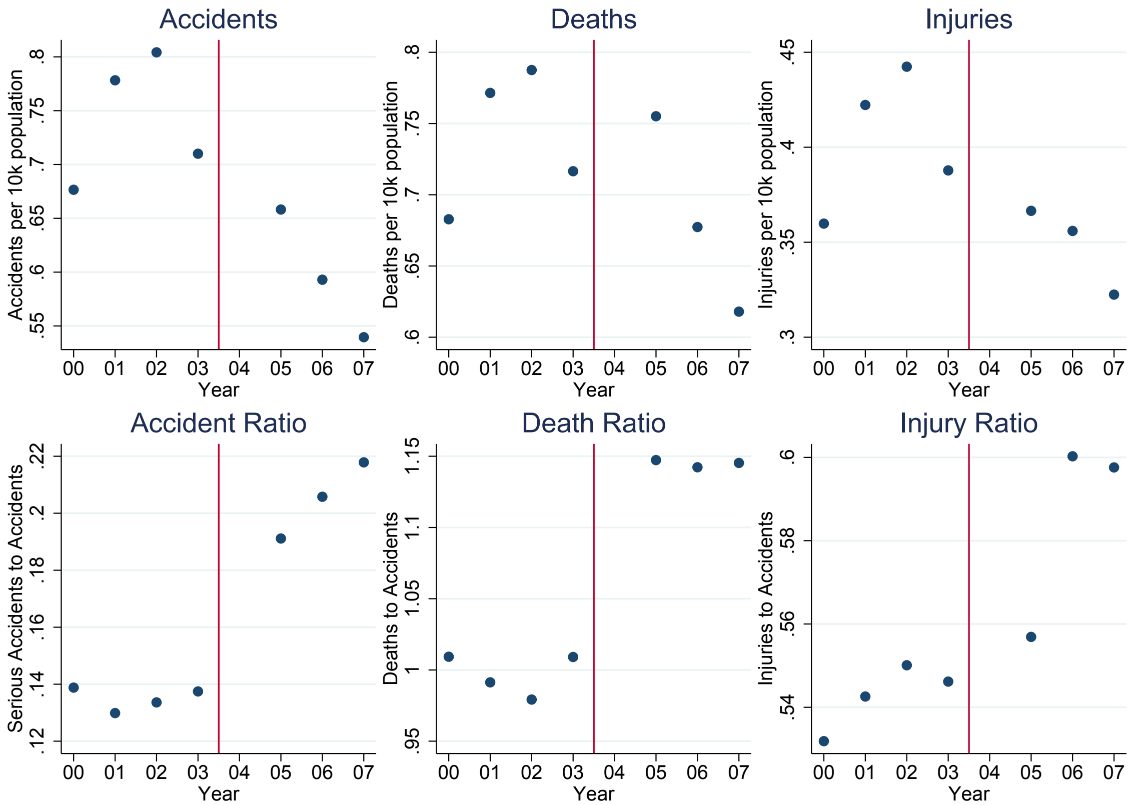
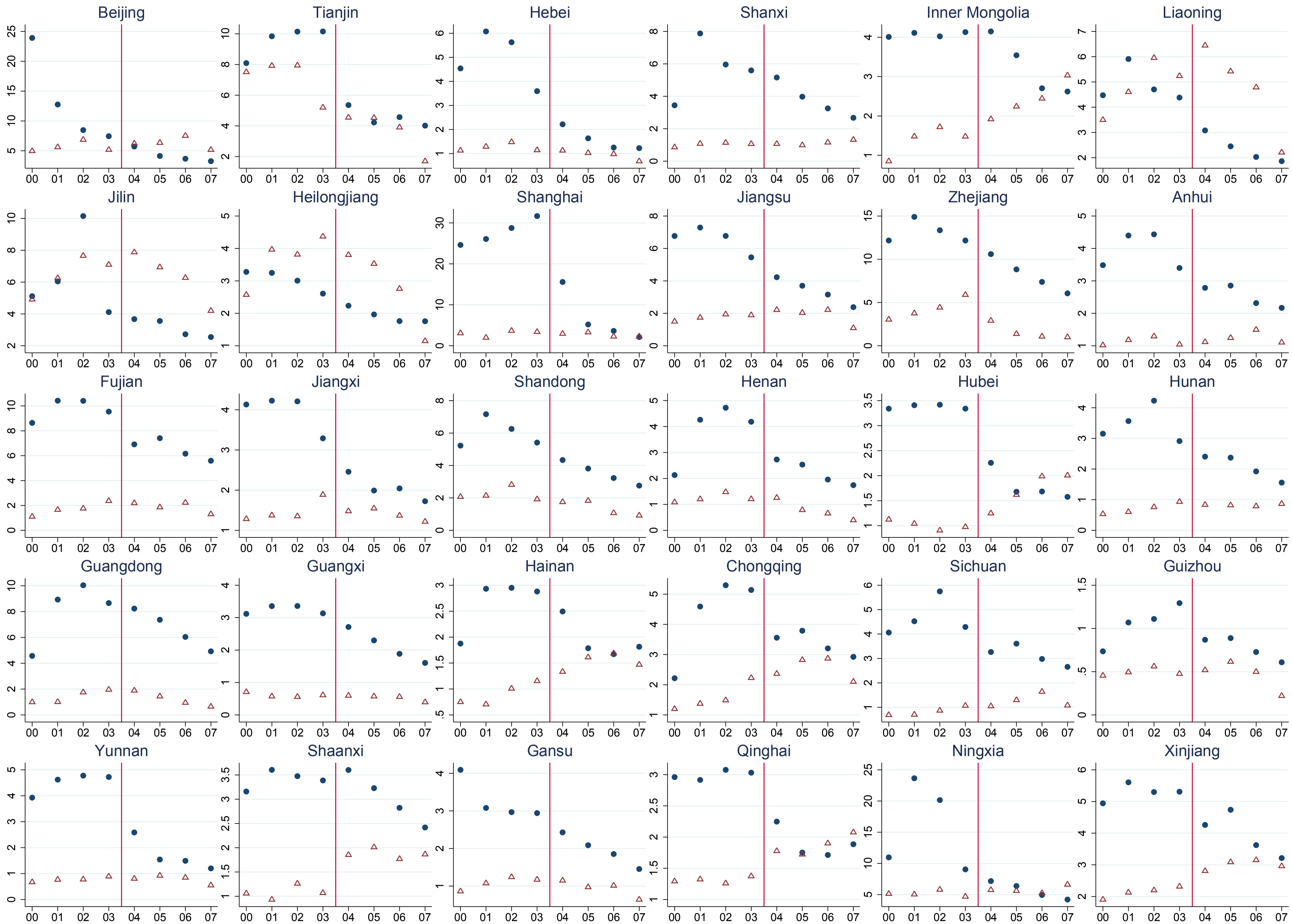
A Data Appendix

Figure A1: Serious Road Traffic Accidents in China



Note: The top panels illustrate the number of serious accident and the number of deaths and injuries arising from serious accidents per 10,000 persons. The bottom panels illustrate the ratio of serious accidents to total accidents and the ratios of deaths and injuries arising from serious accidents to serious accidents. The vertical line illustrates when the RTSL was enacted. Data on serious accidents was not available for 2004.

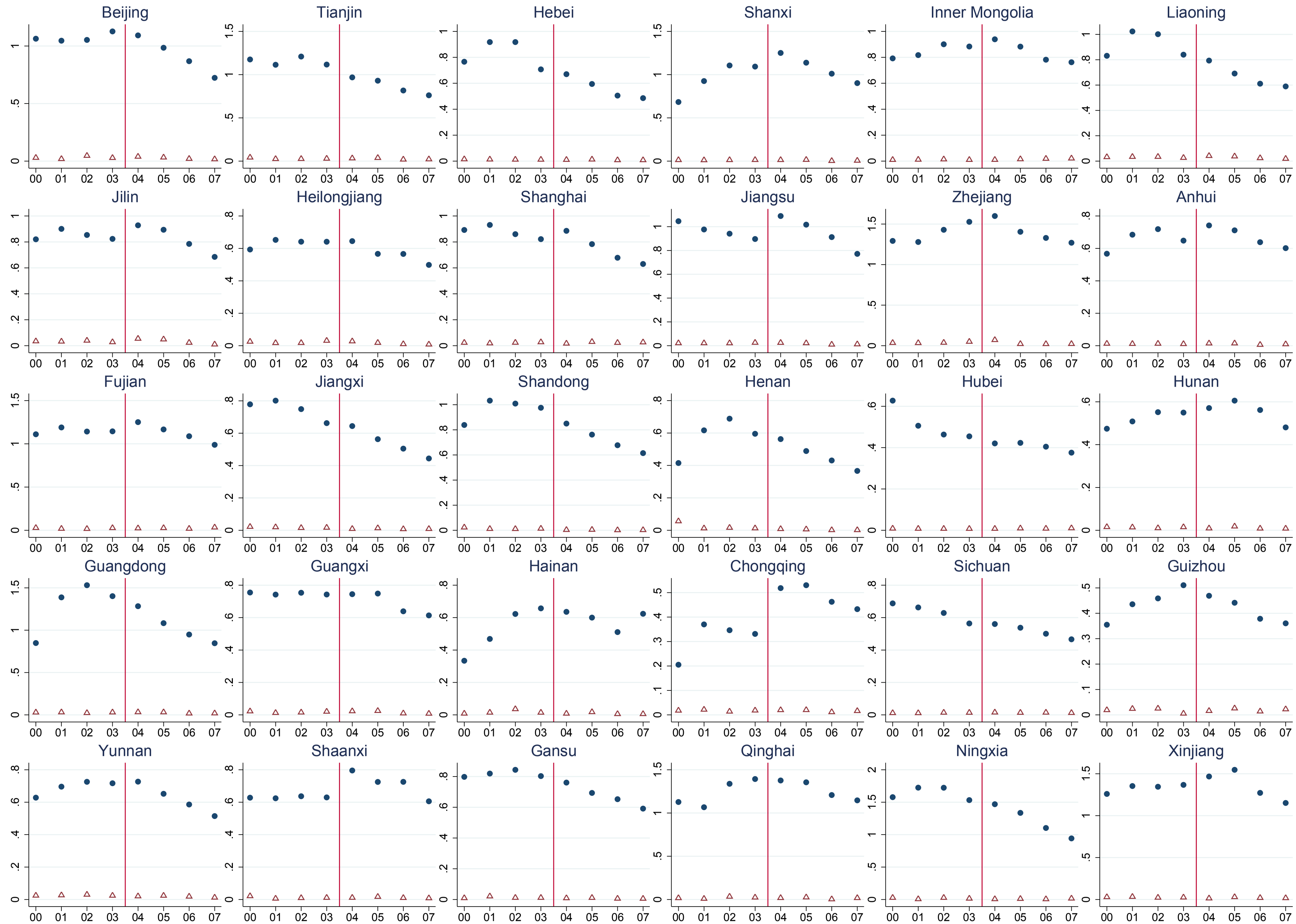
Figure A2: Trends in Road and Fire Accidents



is

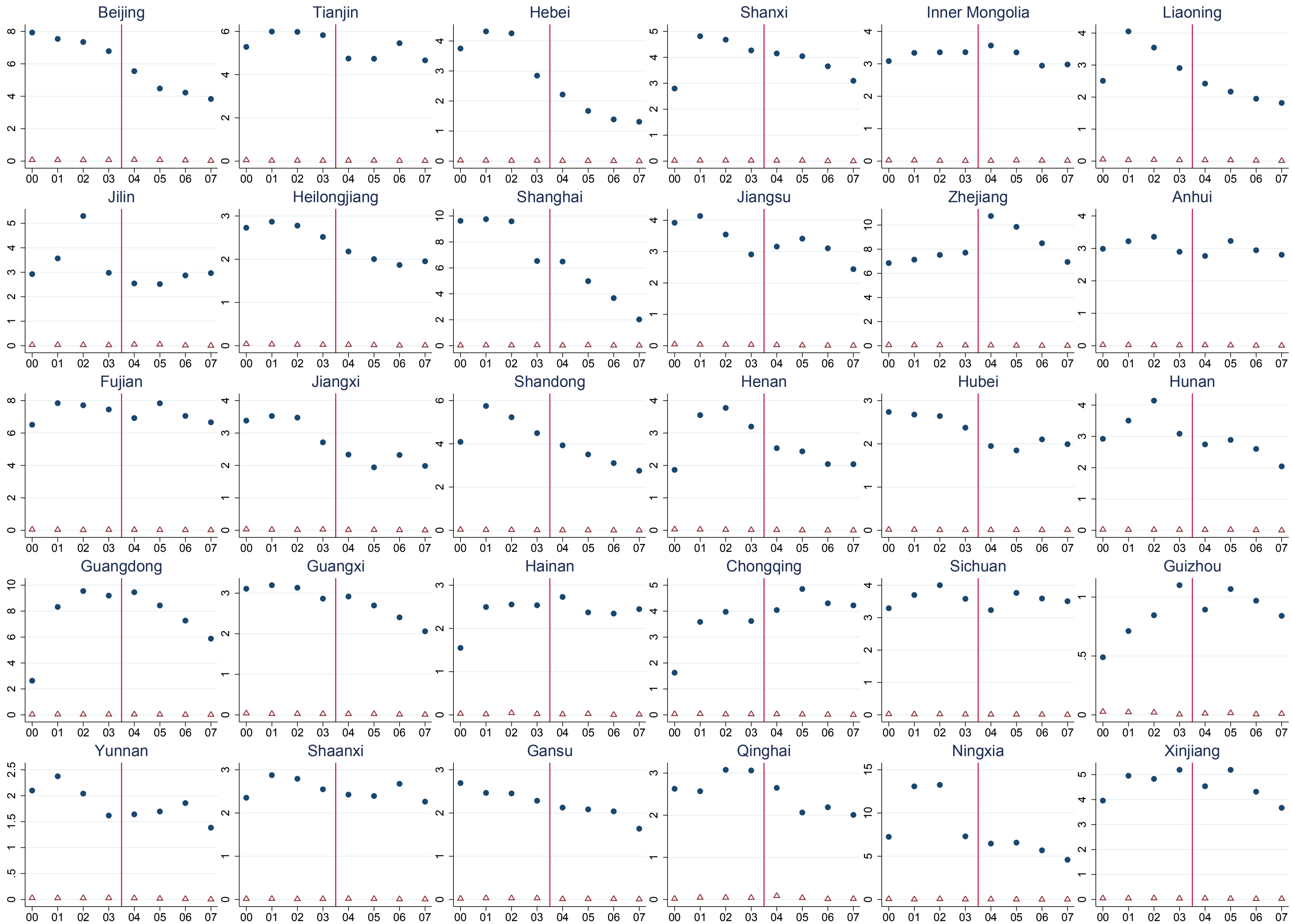
Note: The circles denote road accidents per 10,000 persons and the triangles denote fire accidents per 10,000 persons.

Figure A3: Trends in Road and Fire Deaths



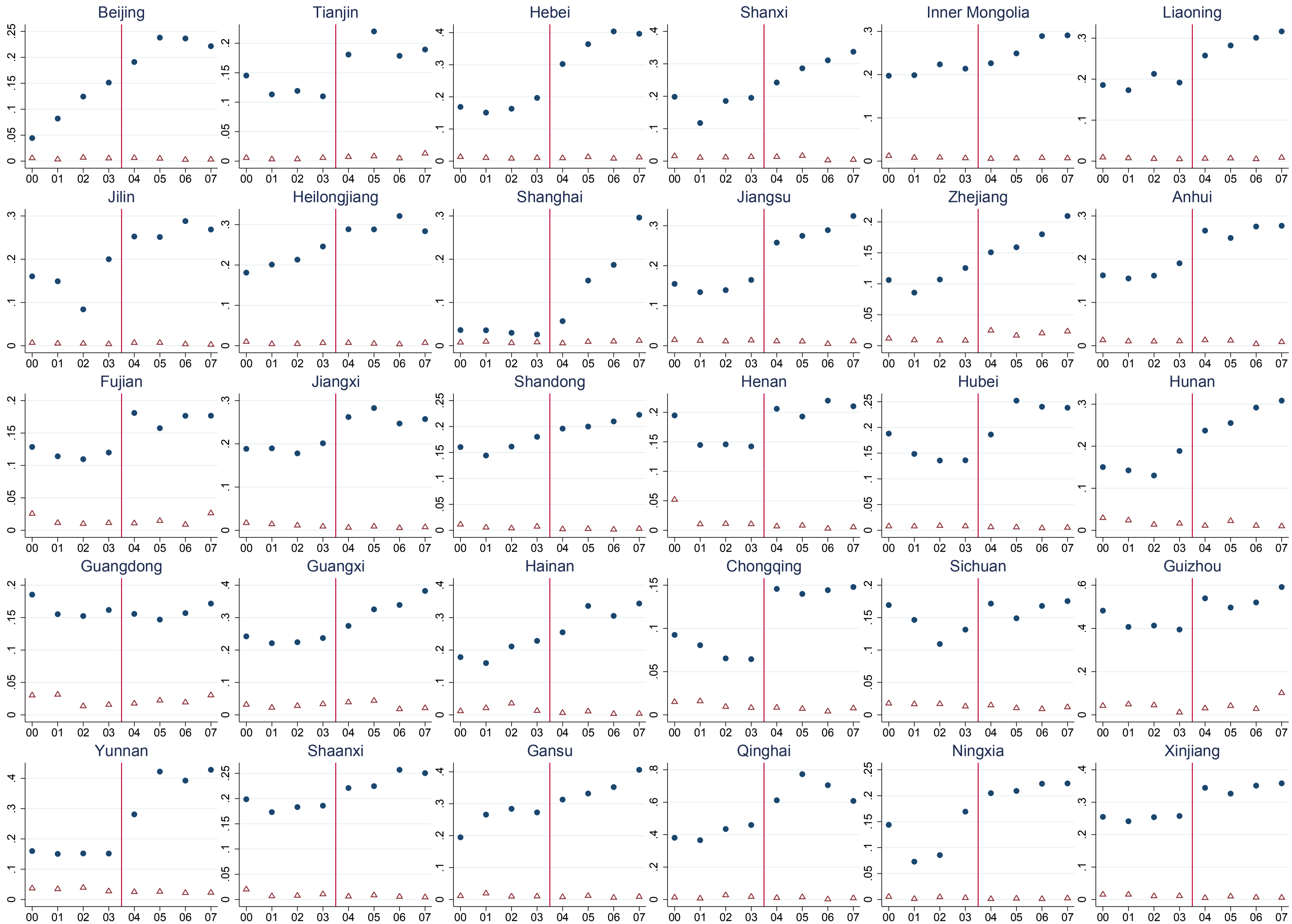
Note: The circles denote road deaths per 10,000 persons and the triangles denote fire deaths per 10,000 persons.

Figure A4: Trends in Road and Fire Injuries



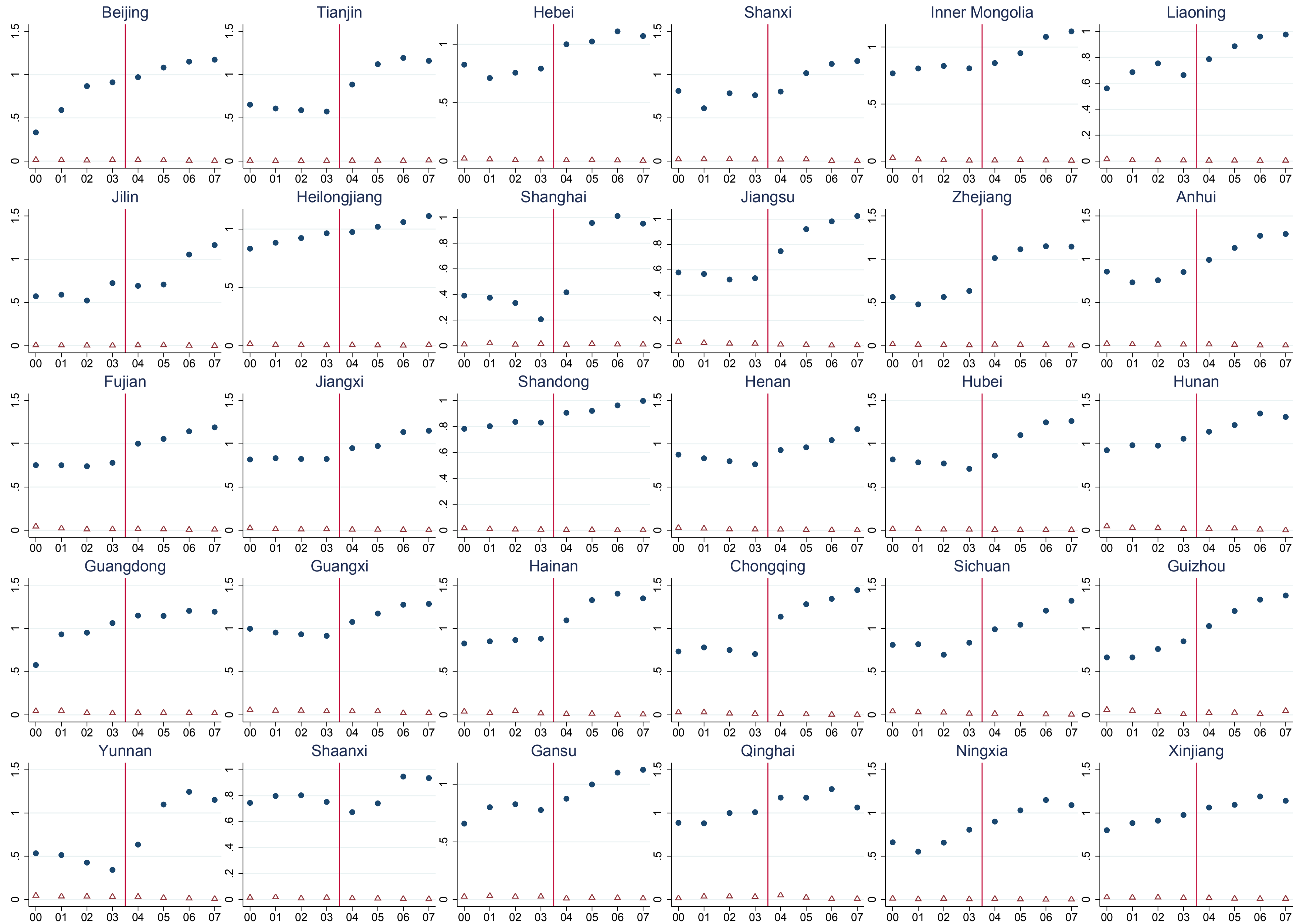
Note: The circles denote road injuries per 10,000 persons and the triangles denote fire injuries per 10,000 persons.

Figure A5: Trends in Road and Fire Death to Accident Ratio



Note: The circles denote road deaths to accidents and the triangles denote fire deaths to accidents.

Figure A6: Trends in Road and Fire Injury to Accident Ratio



Note: The circles denote road injuries to accidents and the triangles denote fire injuries to accidents.

Table A1: Effects of RTSL: Excluding Guandong, Guizhou, Ningxia and Heilongjiang

	Levels			Logarithm		
	(1)	(2)	(3)	(4)	(5)	(6)
Accidents per 10k						
$A_g \times RTSL_t$	-3.021**	-3.628**	-3.522**	-0.478**	-0.486**	-0.486**
	(0.814)	(0.846)	(0.803)	(0.065)	(0.090)	(0.091)
R-squared	0.58	0.78	0.80	0.79	0.86	0.89
Deaths per 10k						
$A_g \times RTSL_t$	-0.059*	-0.115**	-0.119**	-0.032*	-0.064**	-0.066**
	(0.025)	(0.038)	(0.042)	(0.015)	(0.021)	(0.022)
R-squared	0.90	0.96	0.96	0.94	0.97	0.98
Injuries per 10k						
$A_g \times RTSL_t$	-0.710**	-0.948**	-0.925**	-0.147**	-0.202**	-0.200**
	(0.242)	(0.275)	(0.376)	(0.042)	(0.051)	(0.052)
R-squared	0.82	0.91	0.92	0.95	0.97	0.97
Death ratio						
$A_g \times RTSL_t$	0.107**	0.093**	0.093**	0.087**	0.077**	0.077**
	(0.012)	(0.015)	(0.014)	(0.008)	(0.011)	(0.011)
R-squared	0.85	0.93	0.95	0.88	0.94	0.96
Injury ratio						
$A_g \times RTSL_t$	0.336**	0.319**	0.314**	0.183**	0.176**	0.173**
	(0.027)	(0.050)	(0.052)	(0.016)	(0.029)	(0.030)
R-squared	0.96	0.97	0.97	0.97	0.98	0.98
N	416	416	416	416	416	416
Controls						
Covariates		x	x		x	x
Province trend			x			x
Year FE	x	x	x	x	x	x
Province FE	x	x	x	x	x	x

Note: Standard errors clustered at the province level. † $p < .1$, * $p < .05$, ** $p < .01$.

Table A2: Effects of RTSL: 2002 to 2005

	Levels			Logarithm		
	(1)	(2)	(3)	(4)	(5)	(6)
Accidents per 10k						
$A_g \times RTSL_t$	-2.424**	-3.842**	-3.261**	-0.345**	-0.489**	-0.450**
	(0.698)	(1.175)	(1.110)	(0.050)	(0.102)	(0.107)
R-squared	0.61	0.82	0.86	0.80	0.90	0.92
Deaths per 10k						
$A_g \times RTSL_t$	-0.030	-0.112**	-0.103*	-0.015	-0.059**	-0.056**
	(0.023)	(0.041)	(0.046)	(0.012)	(0.020)	(0.023)
R-squared	0.88	0.97	0.97	0.93	0.98	0.98
Injuries per 10k						
$A_g \times RTSL_t$	-0.603**	-1.306*	-1.095†	-0.121**	-0.240**	-0.220*
	(0.212)	(0.534)	(0.551)	(0.031)	(0.078)	(0.089)
R-squared	0.79	0.91	0.92	0.94	0.97	0.98
Death ratio						
$A_g \times RTSL_t$	0.080**	0.106**	0.103**	0.064**	0.085**	0.082**
	(0.010)	(0.023)	(0.025)	(0.007)	(0.017)	(0.019)
R-squared	0.84	0.91	0.92	0.87	0.93	0.93
Injury ratio						
$A_g \times RTSL_t$	0.222**	0.266**	0.252**	0.121**	0.149**	0.140**
	(0.027)	(0.054)	(0.059)	(0.016)	(0.031)	(0.034)
R-squared	0.96	0.97	0.98	0.97	0.98	0.98
N	240	240	240	240	240	240
<u>Controls</u>						
Covariates		x	x		x	x
Province trend			x			x
Year FE	x	x	x	x	x	x
Province FE	x	x	x	x	x	x

Note: Standard errors clustered at the province level. $^{\dagger}\ p < .1, ^{*}\ p < .05, ^{**}\ p < .01$.

B Theoretical Appendix

B.1 Proof of Lemma 1

The motorist's problem in (5) may be rewritten as:

$$\underset{e\geq 0}{Max} \; -\phi p(e,\theta)\mathbb{E}(x|\theta)-e.$$

The first and second order conditions with respect to e are, respectively, given by:

$$-\phi p_e(e(\theta),\theta)\mathbb{E}(x|\theta)-1=0, \tag{B1}$$

$$-\phi p_{ee}(e(\theta),\theta)\mathbb{E}(x|\theta)<0.$$

Totally differentiating the first order condition with respect ϕ, we get

$$-\phi p_{ee}(e(\theta),\theta)\mathbb{E}(x|\theta)\frac{\partial e(\theta)}{\partial \phi}-p_e(e(\theta),\theta)\mathbb{E}(x|\theta)=0.$$

Rearranging, we get

$$\frac{\partial e(\theta)}{\partial \phi}=-\frac{p_e(e(\theta),\theta)}{\phi p_{ee}(e(\theta),\theta)}>0. \tag{B2}$$

Effort increases in the enforcement parameter since $p_e(.)<0$ and $p_{ee}(.)>0$.

B.2 Illustration

Assume the probability density of damages conditional on accident and the probability of accident are given by the following exponential and power functions, respectively:

$$g(x|\theta)=\frac{\exp(-\frac{x}{\theta})}{\theta} \qquad \text{and} \qquad p(e,\theta)=e^{-\frac{1}{\theta}}.$$

Using integration by parts, expected damages is given by $\mathbb{E}(x|\theta)=\int_0^\infty x\frac{\exp(-\frac{x}{\theta})}{\theta}dx=\theta$.

We can then rewrite the motorist's problem as:

$$\underset{e\geq 0}{Max} \; -\phi e^{-\frac{1}{\theta}}\theta-e.$$

From the first order condition with respect to e, we have $e(\theta)=\phi^{\frac{\theta}{1+\theta}}$. Thus, the equilibrium probability of causing an accident is given by:

$$p(e(\theta),\theta)=\phi^{-\frac{1}{1+\theta}}.$$

It is straightforward to see that Conditions 1 and 2 are satisfied when $\phi>1$.

B.3 Proof of Proposition 1

Differentiating the death to accident ratio with respect to ϕ, we get:

$$\frac{\partial r(\phi,F)}{\partial\phi}=\frac{\left[\begin{array}{c}\int_0^1\gamma(x_D|\theta)\frac{\partial p(e(\theta),\theta)}{\partial\phi}dF(\theta)\int_0^1 p(e(\theta),\theta)\,dF(\theta)\\-\int_0^1\gamma(x_D|\theta)\,p(e(\theta),\theta)\,dF(\theta)\int_0^1\frac{\partial p(e(\theta),\theta)}{\partial\phi}dF(\theta)\end{array}\right]}{\left[\int_0^1 p(e(\theta),\theta)\,dF(\theta)\right]^2}, \tag{B3}$$

where, using the motorist's first order condition with respect to e (i.e., eq. (B1) and (B2) above), we get:

$$\frac{\partial p(e(\theta),\theta)}{\partial\phi}=p_e(e(\theta),\theta)\frac{\partial e(\theta)}{\partial\phi}=\frac{1}{\phi^2\mathbb{E}(x|\theta)}\frac{p_e(e(\theta),\theta)}{p_{ee}(e(\theta),\theta)}=-s(\theta).$$

Now, since the denominator in equation (B3) is positive, $\frac{\partial r(\phi,F)}{\partial\phi}>0$ if

$$\int_0^1\gamma(x_D|\theta)\frac{\partial p(e(\theta),\theta)}{\partial\phi}dF(\theta)\int_0^1 p(e(\theta),\theta)\,dF(\theta)$$
$$>\int_0^1\gamma(x_D|\theta)\,p(e(\theta),\theta)\,dF(\theta)\int_0^1\frac{\partial p(e(\theta),\theta)}{\partial\phi}dF(\theta), \tag{B4}$$

which may be rearranged as

$$\int_0^1\gamma(x_D|\theta)\,s(\theta)\,dF(\theta)\int_0^1 p(e(\theta),\theta)\,dF(\theta)<\int_0^1\gamma(x_D|\theta)\,p(e(\theta),\theta)\,dF(\theta)\int_0^1 s(\theta)\,dF(\theta). \tag{B5}$$

Recall that riskier drivers cause more deaths than safer drivers such that $\gamma(x_D|\theta)$ is increasing in θ. In addition, Condition 1 ensures that $s(\theta)$ is decreasing in θ while Condition 2 ensures that $p(e(\theta),\theta)$ is increasing in θ. Chebyshev's sum inequality implies the following two inequalities:

$$\int_0^1\gamma(x_D|\theta)\,s(\theta)\,dF(\theta)<\int_0^1\gamma(x_D|\theta)\,dF(\theta)\int_0^1 s(\theta)\,dF(\theta), \tag{B6}$$

$$\int_0^1\gamma(x_D|\theta)\,dF(\theta)\int_0^1 p(e(\theta),\theta)\,dF(\theta)<\int_0^1\gamma(x_D|\theta)\,p(e(\theta),\theta)\,dF(\theta). \tag{B7}$$

Multplying inequalities (B6) and (B7) with $\int_0^1 p(e(\theta),\theta)\,dF(\theta)$ and $\int_0^1 s(\theta)\,dF(\theta)$, respectively, we can see that inequality (B5) is satisfied. Thus, the death to accident ratio increases with higher enforcement. In a similar fashion, we can show that if Conditions 1 and 2 are reversed, then inequalities (B6) and (B7) are reversed such that we get a decrease in death rates when ϕ increases.

B.4 Generalized Model

Suppose that drivers' problem may be rewritten as:

$$\max_e\ -\phi p(e,\theta)\mathbb{E}(x|e,\theta)-c(e,\theta). \tag{B8}$$

The first and second order conditions for this problem are, respectively

$$-\phi p_e(e(\theta),\theta)\mathbb{E}(x|e(\theta),\theta)-\phi p(e(\theta),\theta)\int_x xg_e(x|e(\theta),\theta)dx = c_e(e(\theta),\theta), \tag{B9}$$

$$-\phi p_{ee}(e,\theta)\mathbb{E}(x|e,\theta)-2\phi p_e(e,\theta)\int_x xg_e(x|e,\theta)dx-\phi p(e(\theta),\theta)\int_x xg_{ee}(x|e,\theta)dx-c_{ee}(e,\theta)<0, \tag{B10}$$

where g_e and g_{ee} denote the first and second derivative of $g(x|e,\theta)$, the probability density function (pdf) of damages conditional on accident, with respect to e. Assume that $g(x|e,\theta)$ is decreasing in e such that expected damages decrease in effort. Provided that (B10) is satisfied, we have a unique $e(\theta)$ that satisfies (B9).

Differentiating (B9) with respect to ϕ, we get

$$\frac{\partial e(\theta)}{\partial \phi} = -\frac{p_e(e(\theta),\theta)\mathbb{E}(x|e(\theta),\theta)+p(e(\theta),\theta)\int_x xg_e(x|e(\theta),\theta)dx}{\begin{bmatrix}\phi p_{ee}(e(\theta),\theta)\mathbb{E}(x|e(\theta),\theta)+2\phi p_e(e(\theta),\theta)\int_x xg_e(x|e(\theta),\theta)dx \\ +\phi p(e(\theta),\theta)\int_x xg_{ee}(x|e(\theta),\theta)dx+c_{ee}(e(\theta),\theta)\end{bmatrix}} > 0,$$

where the inequality stems from the fact that the denoninator is positive from (B10), while the numerator (including the minus sign) is positive by the assumption that $p_e<0$ and $g_e<0$. Thus, driving effort increases with ϕ such that the number of accidents and casualties decrease.

Let $\gamma(x_D|e(\theta),\theta)=1-G(x_D|e(\theta),\theta)$. Consider the following condition:

$$\left(\int_0^1 p(e(\theta),\theta)\frac{\gamma(x_D|e(\theta),\theta)}{\partial\phi}dF(\theta)+\int_0^1 \gamma(x_D|e(\theta),\theta)\frac{\partial p(e(\theta),\theta)}{\partial\phi}dF(\theta)\right)\int_0^1 p(e(\theta),\theta)dF(\theta)$$
$$>\int_0^1 \gamma(x_D|e(\theta),\theta)p(e(\theta),\theta)dF(\theta)\int_0^1\frac{\partial p(e(\theta),\theta)}{\partial\phi}dF(\theta). \tag{B11}$$

Proposition 3. *If the inequality (B11) is satisfied, then an increase in enforcement will lead to an increase in the death to accident ratio. If the inequality (B11) is reversed, then an increase in enforcement will lead to a decrease in the death to accident ratio.*

Proof. The death to accident ratio can be expressed as

$$r(\phi)=\frac{\int_0^1 \gamma(x_D|e(\theta),\theta)p(e(\theta),\theta)dF(\theta)}{\int_0^1 p(e(\theta),\theta)dF(\theta)}. \tag{B12}$$

Differentiating (B12) with respect to ϕ, we find that the death ratio is increasing in ϕ when (B11) is satisfied, whereas the death ratio is decreasing in ϕ when (B11) is reversed. □

It is easy to see that when the distribution of damages does not depend of effort and consequently $\frac{\partial\gamma(x_D|e(\theta),\theta))}{\partial\phi}=0$, the inequality in (B11) collapses to the one in (B4). Hence, assuming (B10) is satisfied, the death to accident ratio is increasing in ϕ if the inequality in (B11) is satisfied and is decreasing in ϕ if the inequality in (B11) is reversed. In the special case considered in our main model, where the cost of effort is linear and the distribution of damages conditional on accident does not depend on driver effort, Conditions 1 and 2 ensure that the inequality in (B4) holds. These conditions continue to be sufficient for (B11) to hold in the generalized model, as long as $\frac{\partial\gamma(x_D|e(\theta),\theta)}{\partial\phi}\geq 0$. However, if $\frac{\partial\gamma(x_D|e(\theta),\theta)}{\partial\phi}<0$, then the death to accident ratio changes in an indeterminate fashion [decreases] when Conditions 1 and 2 continue to hold [are reversed].

B.5 Proof of Lemma 2

For Part 1, it is straightforward to see that if $\pi(x)\tau(x)$ is convex [concave], since $\pi(0)\tau(0)=0$ and $\lim_{x\to\infty}\pi(x)\tau(x)>x$ $\left[\lim_{x\to\infty}\pi(x)\tau(x)<x\right]$, then there exists a $x^*\geq 0$, such that $x\leq\pi(x)\tau(x)$ for $x\geq x^*$ $[x\leq x^*]$ and $x>\pi(x)\tau(x)$ for $x<x^*$ $[x>x^*]$. For Part 2, by inspection, we can see that an increase in $\pi(.)\tau(.)$ resulting from an increase in $\pi(.)$, $\tau(.)$ or both, will lead to a decrease [increase] in x^* when $\pi(x^*)\tau(x^*)$ is convex [concave].

B.6 Proof of Proposition 2

Note that the incentive to report an accident is independent of the motorist's type, θ, and depends only on the realization of damages, x.

Convex $\pi(x)\tau(x)$ Suppose that $\pi(x)\tau(x)$ is convex so that (i) all accidents with $x\geq x^*$ are reported and (ii) x^* decreases with the strictness of the law: $x_1^*<x_0^*$. Since x^* decreases, then the likelihood than an accident gets reported increases: $1-G(x_1^*|\theta)>1-G\left(x_0^*|\theta\right)$. Next, consider the likelihood of reporting an accident involving death and the reported death ratio. First, if $x_D<x_1^*<x_0^*$, then the likelihood of reporting an accident involving death increases from $\frac{1-G\left(x_0^*|\theta\right)}{1-G(x_D|\theta)}$ to $\frac{1-G\left(x_1^*|\theta\right)}{1-G(x_D|\theta)}$ [reported death ratio remains unchanged at $\frac{1-G\left(x_0^*|\theta\right)}{1-G\left(x_0^*|\theta\right)}=\frac{1-G\left(x_1^*|\theta\right)}{1-G\left(x_1^*|\theta\right)}=1$]. Second, if $x_1^*<x_D<x_0^*$, then the likelihood of reporting an accident involving death increases from $\frac{1-G\left(x_0^*|\theta\right)}{1-G(x_D|\theta)}$ to $\frac{1-G(x_D|\theta)}{1-G(x_D|\theta)}=1$ [reported death ratio decreases from $\frac{1-G\left(x_0^*|\theta\right)}{1-G\left(x_0^*|\theta\right)}=1$ to $\frac{1-G(x_D|\theta)}{1-G\left(x_1^*|\theta\right)}$]. Third, if $x_1^*<x_0^*<x_D$, then the likelihood of reporting an accident involving death remains unchanged at $\frac{1-G(x_D|\theta)}{1-G(x_D|\theta)}=1$ [reported death ratio decreases from $\frac{1-G(x_D|\theta)}{1-G\left(x_0^*|\theta\right)}$ to $\frac{1-G(x_D|\theta)}{1-G\left(x_1^*|\theta\right)}$]. Thus, the likelihood of reporting deaths cannot decrease and the reported death ratio cannot increase as a result of an increase in the strictness of the law.

Concave $\pi(x)\tau(x)$ Now, suppose that $\pi(x)\tau(x)$ is concave so that (i) all accidents with $x\leq x^*$ are reported and (ii) x^* increases with the strictness of the law: $x_1^*>x_0^*$. Since x^* increases, then the likelihood than an accident gets reported increases: $G(x_1^*|\theta)>G\left(x_0^*|\theta\right)$. Next, consider the likelihood of reporting an accident involving death and the reported death ratio. First, if $x_D<x_0^*<x_1^*$, then the likelihood of reporting an accident involving death increases from $\frac{G\left(x_0^*|\theta\right)-G(x_D|\theta)}{1-G(x_D|\theta)}$ to $\frac{G\left(x_1^*|\theta\right)-G(x_D|\theta)}{1-G(x_D|\theta)}$ [reported death ratio increases from $\frac{G\left(x_0^*|\theta\right)-G(x_D|\theta)}{G\left(x_0^*|\theta\right)}$ to $\frac{G\left(x_1^*|\theta\right)-G(x_D|\theta)}{G\left(x_1^*|\theta\right)}$]. Second, if $x_0^*<x_D<x_1^*$, then the likelihood of reporting an accident involving death increases from $\frac{0}{1-G(x_D|\theta)}$ to $\frac{G\left(x_1^*|\theta\right)-G(x_D|\theta)}{1-G(x_D|\theta)}$ [reported death ratio increases from 0 to $\frac{G\left(x_1^*|\theta\right)-G(x_D|\theta)}{G\left(x_1^*|\theta\right)}$]. Third, if $x_0^*<x_1^*<x_D$, then the likelihood of reporting an accident involving death remains unchanged at $\frac{0}{1-G(x_D|\theta)}=0$ [reported death ratio remains unchanged at 0]. Thus, the likelihood of reporting deaths cannot decrease and the reported death ratio cannot decrease as a result of an increase in the strictness of the law.