

**ONCE TICKETED, TWICE SHY?
SPECIFIC DETERRENCE FROM ROAD TRAFFIC LAWS**

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ABSTRACT

Does the experience of being penalized for a traffic offense cause drivers to drive more safely than they otherwise would? Answering that question empirically involves a difficult counterfactual and existing research has not answered it well. In the Australian state of Queensland, cameras are widely used to detect the two most common types of offenses: speeding and red-light running. It typically takes about two weeks for camera-detected offenders to be notified they have been caught. We followed a cohort of nearly three million drivers from the time of their offense, through notification, and 90 days afterwards. We used a regression discontinuity design to examine whether rates of crashes and recidivism in this cohort changed after notification. We find no evidence that notification decreased crashes. However, a sharp decrease in reoffending is evident—25% for the cohort as a whole and up to 40% for some subgroups of drivers. The implications of these findings for understanding the specific deterrent effects of traffic laws on road safety are discussed.

I. INTRODUCTION

Motor vehicle accidents inflict a devastating toll on human life and well-being. In 2010, they killed 1.3 million people worldwide (3% of all deaths) and caused 78 million injuries serious enough to require medical care.¹ They rank 8th among the leading causes of premature mortality,² and are projected to rise to 4th by 2030.³

Much of this injury burden falls on developing countries. Developed countries, and some middle-income countries, have made huge gains in road safety over the last 50 years. The decline in road traffic injuries—due primarily to safer vehicle and roadway redesign, seatbelts, and reductions in speeding and drunk driving—stands as one of the great public health victories of the twentieth century.⁴ However, motor vehicle accidents remain a major cause of mortality and morbidity in rich countries. In the United States, for example, nearly 35,000 people die on the road each year and 2.3 million are injured,⁵ at an estimated total cost of \$100 billion.⁶ Part of the immense social cost stems from the disproportionately high incidence of car crashes among the young: car crashes are the leading cause of death and injury among Americans 4-34 years of age.⁷

Laws governing the use of mechanically propelled vehicles appeared in the mid-nineteenth century, well before petrol-powered automobiles were commercially available.⁸ The “red flag” traffic laws, enacted by the British Parliament in 1865, are recognized as among the first. They imposed a speed limit of four miles per hour and mandated a three-man crew for every vehicle, one of whom was to walk ahead to

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1. Global Road Safety Facility. The World Bank & Institute for Health metrics and Evaluation, University of Washington. *Transport for health: the global burden of disease from motorized road transport*. Seattle, WA; Washington DC: The World Bank, 2014; Lozano R, et al. (2012). Global and regional mortality from 235 causes of death for 20 age groups in 1990 and 2010: a systematic analysis for the Global Burden of Disease Study 2010. *The Lancet*, 380(9859), 2095-2128.
 2. Murray CJL, et al. (2012). Disability-adjusted life years (DALYs) for 291 diseases and injuries in 21 regions, 1990-2010: a systematic analysis for the Global Burden of Disease Study 2010. *The Lancet*, 380: 2197-2223.
 3. Mathers CD, Loncar D (2006) Projections of Global Mortality and Burden of Disease from 2002 to 2030. *PLoS Med* 3(11): e442.
 4. Peden M, Scurfield R, Sleet D, et al (eds). *World Report on Road Traffic Injury Prevention*. Geneva: World Health Organization, 2004; Dellinger AM, Sleet DA, Jones BH. *Drivers, Wheels, and Roads: Motor Vehicle Safety in the Twentieth Century*, in Ward JW, Warren C. *Silent Victories: The History and Practice of Public Health in Twentieth-Century America*. New York, NY: Oxford University Press, 2006.
 5. National Highway Transportation Safety Agency. *Traffic safety facts: 2012 Data*. DOT HS 812 016 (May 2014).
 6. Naumann RB, Dellinger AM, Zaloshnja E, Lawrence BA, Miller TR. Incidence and total lifetime costs of motor vehicle-related fatal and nonfatal injury by road user type, United States, 2005. *Traffic Inj Prev* 2010;11:353-60.
 7. Centers for Disease Control. Nonfatal, motor vehicle-occupant injuries (2009) and seat belt use (2008) among adults—United States. *MMWR* 2011;1681-86; Subramanian R. Motor vehicle traffic crashes as a leading cause of death in the United States, 2006. DOT HS 811 226 (Oct 2009).
 8. Oliphant K. Tort law, risk, and technological innovation in England. 59 *McGill L.J.* 819 (2014).

warn bystanders of the approaching car by means of “a red flag constantly displayed”.⁹

Today, traffic laws are ubiquitous. Getting a ticket, or hearing of a friend or family member who got one, is not exactly a routine event, but it might be the occasion for no more surprise and anguish than would greet, say, losing one’s credit card or having a particularly bad day at work. Governments promulgate elaborate lists of road rules, which are designed to mitigate hundreds of different behaviours—from speeding and stoplight breaches to carriage of excessive loads and driving under the influence of alcohol. Many—though clearly not all—of these sanctioned behaviours are empirically-established risk factors for accidents.¹⁰

Enforcement occurs on a vast scale. A 2010 analysis of US state courts counted 58 million traffic offenses under judicial management in that year; they accounted for 54% of the aggregate trial court caseload.¹¹ The vast majority of these charges are resolved outside court.¹² Nonetheless, with a median incidence of 18 offenses per 100 persons per year,¹³ traffic law violations must surely rank as the most common point of contact Americans have with any punitive side of the legal system.

Although the detail, scale, and reach of traffic laws expanded dramatically over the twentieth century, the core rationale of these regimes remains essentially unchanged from the red flag days: they exist to protect the public’s health. The standard account of how this outcome is achieved turns on deterrence: sanctioning risky driving practices discourages them, thereby improving safety.¹⁴

To what extent do traffic laws actually achieve their foundational safety objectives? And in what ways does deterrence shape driver behaviour? This study aimed to add to the empirical evidence base available to answer those fundamental questions. Our focus was specific deterrence. We searched for evidence of its imprint on recidivism and crash rates, drawing on a large dataset of driver, offense, and crashes records from the Australian state of Queensland.

9. The Locomotive Act 1865, 28 & 29 Vict. C. 83, s.3.

10. Some behaviours are sanctioned because of their role in reducing the severity of injuries when accidents occur, rather than the incidence of accidents. Rules regarding use of seatbelts and motorcycle helmets are two examples.

11. LaFountain R, Schauffler R, Strickland S, Holt K. Examining the work of state courts: An analysis of 2010 state court caseloads. (National Center for State Courts 2012). (Note: The category used in this analysis is actually titled “traffic/violations”, and it includes some non-traffic related violations, such as breaches of ordinances. However, state-specific sub-analyses presented in the report suggest that traffic offenses account for about 90-95% of the total counts in this category.)

12. The figures reported by the National Center for State Courts are based on tallies across state courts. Cases from single-tiered courts, courts of general jurisdiction, courts of limited jurisdiction are combined. In some states parking tickets fall under court jurisdiction, in which case they contributed to the caseload totals from these jurisdictions. However, many states assign parking ticket enforcement to a separate administrative agency, in which case they do not figure in caseload totals. But even in states where parking tickets are excluded, traffic offenses remain a very large proportion of total court caseloads. Take California, whose case total exclude parking tickets. The state had 6.4 million incoming traffic offenses in 2010, which represents 61% of all civil, criminal, and other cases in the state court system.

13. LaFountain et al, supra note 11.

14. Andenæs J. Punishment and deterrence. Ann Arbor: University of Michigan Press, 1974.

In the next section, we sketch a simple theoretical model of deterrence in the context of traffic penalties. Part III reviews the literature on traffic law deterrence. Part IV discusses some of the difficulties with causal inference in this area. Part V describes our study approach. Part VI reports results. Part VII discusses the study findings and considers their implications for law and road safety policy. Part VIII concludes.

II. PATHWAYS AND TARGETS

Classic deterrence theory describes two distinct mechanisms of action.¹⁵ “General deterrence” refers to the threat of punishment prevailing in society at large. In the road traffic context, this is the diffuse signal emanating from the very existence of a rule or regime; drivers seek to obey road rules because they realize they risk fines and penalties if they break them. “Specific deterrence” comes from direct personal experience. Drivers who infringe road rules get caught and are penalized, and then learn their lesson; they become less likely to reoffend, which indirectly leads them to drive more safely and have fewer accidents.

Figure 1 presents a simple illustration of the pathways through which general and specific deterrence are theorized to influence road safety. General deterrence is scattershot; it may simultaneously affect drivers’ propensity to offend, the safety with which they drive, and their risk of crashing. Specific deterrent signals travel along a more structured pathway. The penalty experience reduces propensity to offend and to drive dangerously, in that order, or possibly simultaneously. The net effect of those behavioral changes is a reduction in crash risk.

The classic model of deterrence has long been an intellectual punching bag. There are many lines of attack. The clarity of the conceptual distinction between general and specific deterrence, for example, is hotly debated. Criminal justice scholars have also questioned the severability of deterrent effects from others determinants of behavior change, such as incapacitation and rehabilitation. And Stafford and Warr’s widely-discussed reconceptualization of deterrence theory posits that far too little attention has been paid to the “anti-deterrent” effects that flow from personal experiences with committing offenses that go unsanctioned.¹⁶

We would readily agree that the orthodox accounts of deterrence are incomplete and, of particular relevance to our study, that the dividing lines between different forms of deterrence are not always bright. Nonetheless, in describing the behavioral effects under investigation among Queensland drivers we generally stick

15. Zimring FE, Hawkins GJ. Deterrence: the legal threat in crime control. Chicago: Univ Chicago Press, 1973; Shavell S. Foundations of economic analysis of law. Cambridge, MA: Harvard University Press, 2004; Kahan D. The secret ambition of deterrence. Harv Law Rev. 1999;113:413–500

16. Stafford M, Warr M. A reconceptualization of general and specific deterrence. Journal of Research in Crime and Delinquency. 1993;30:123-35; Piquero A, Paternoster R. An application of Stafford and Warr’s reconceptualization of deterrence to drinking and driving. J Res Crime Delinq. 1998;35(1):3-39.

with the traditional constructs and nomenclature. We do so partly for reasons of expediency. But it is also worth pointing out that a couple of aspects of our study design help to deflect some of most trenchant theoretical attacks. Specifically, we search for evidence of specific deterrence within a time frame that is short—short enough to discount rival explanations for any behavioral changes observed.¹⁷ In addition, we observe which Queensland drivers had their licenses lapse or become suspended or revoked, when, and for how long. “Censoring” those periods from the analysis helps to separate true deterrent effects from incapacitation effects (i.e. lack of exposure to the risks under study).

III. WHAT IS KNOWN ABOUT THE DETERRENT EFFECTS OF TRAFFIC LAWS

Over the last 40 years dozens of studies have sought to measure deterrent effects associated with traffic laws. The body of research converges tightly around two outcomes: recidivism and crashes. In other respects, however, it is quite heterogeneous.

Drunk driving studies

Perhaps the most striking feature of the traffic law deterrence literature is that the overwhelming majority of studies focus on drunk driving. An obvious explanation is the important causal role of alcohol in crashes.¹⁸ Other factors are also at work. The sharp rise in the prevalence and severity of drunk driving laws since the 1970s, coupled with the availability of high-quality population-level data on offenders and road accidents, have created abundant opportunities for research. Further, the large number of studies examining recidivist drunk driving almost certainly reflects the leadership of criminologists in this area.

Drunk driving studies are included in the literature review of general and specific deterrence that follows—without them the review would be short and the evidence base remarkably thin. There are good reasons, however, to be cautious about extrapolating from findings in those studies to surmise the nature of deterrent effects of traffic laws more broadly. First, drunk drivers account for a small minority of penalized offenders. In Queensland, for example, over the 16-year period we examined, less than 2% of the 11.6 million recorded offenses were DUIs. Second, driving under the influence of alcohol or drugs sits at the egregious end of the traffic offense spectrum. It is commonly treated as a crime, whereas most other types of traffic offenses are civil or administrative in nature, and are sanctioned by fines and

17. The tradeoff is that we are not positioned to draw inferences about how enduring specific deterrent effects are.

18. In the US in 2012, for example, 10,322 deaths, or 31 percent of all road fatalities, occurred in alcohol-impaired-driving crashes. These figures have declined steeply over the last 30 years. In 1982, 57% of the 43,945 traffic fatalities were alcohol-related. *See* National Highway Transportation Safety Administration, Traffic Safety Facts: Alcohol-impaired driving DOT HS 811 870. December 2013.

license demerit points.¹⁹ Third, owing to their criminal nature, drunk driving offenses often trigger penalties such as license suspension, vehicle impoundment, and, for repeat offenders, incarceration.²⁰ Such incapacitating interventions have been associated with some of the most impressive deterrent effects detected in the literature.²¹ However, as noted above, these studies generally do not disentangle safer driving responses from drivers' reduced or complete lack of exposure to driving during the penalty period, and the latter is not a species of deterrence. Finally, the prevalence of alcohol addiction among drunk drivers may mute their susceptibility to deterrent effects, although this theory is controversial.²²

General deterrence

Nearly all studies of general deterrence from traffic laws employ the same design: they are before-and-after comparisons of accident rates and/or recidivism, centered on the introduction of new penalties or enhancements of existing ones. Two laws that have consistently demonstrated large safety effects are the lowering of permissible levels of blood-alcohol concentration (BAC)²³ and pre-conviction license suspensions for drunk drivers.²⁴ Isolating general deterrent effects in ecological pre/post studies is

19. While it may be tempting to infer from that distinction that drunk driving laws should therefore set the high-water mark for deterrent effects, that conclusion ignores research suggesting that: (1) severity of punishment is a poor predictor of safer driving; and (2) drunk driving offenders, especially recidivist drunk drivers, tend to be an atypical kind of traffic offender. *See* Nochajski TH, Stasiewicz PR.

Relapse to driving under the influence (DUI): a review. *Clin Psychol Rev* 2006;26(2):179-95.

20. Under so-called "administrative per se" laws, around 30 states now suspend licenses immediately, at the point of test failure. *See* Wagenaar et al, *infra* note 24.

21. *See, for e.g.*, Zaldor PL, Lunk AK, Fields M, Weinberg K. Fatal crash involvement and laws against alcohol-impaired driving. *Journal of Public Health Policy* 1989;10:467-485; Voas RB, Tippetts AS, Fell JC. The relationship of alcohol safety laws to drinking drivers in fatal crashes. *Accident Analysis and Prevention* 2000;32:483-92.

22. Nochajski, Miller, Parks. Comparison of first time and repeat DWI offenders. *Alcoholism: Clinical and Experimental Research* 1994;18:48; Wiczorek and Nochajski. Characteristics of persistent drinking drivers; Yu and Williford 1993, Problem drinking and hi-risk driving ; Yu J, Chin Evans P, Perfetti Clark L. Alcohol addiction and perceived sanction risks: Deterring drinking drivers. *J Crim Justice*. 2006;34:165-174.

23. Wagenaar AC, Maldonado-Molina MM, Ma L, Tobler AL, Komro KA. Effects of legal BAC limits on fatal crash involvement: analyses of 28 States from 1976 through 2002. *J Safety Res*. 2007;38:493-499; Fell JC, Voas RB. The effectiveness of reducing illegal blood alcohol concentration (BAC) limits for driving: evidence for lowering the limit to .05 BAC. *J Saf Res* 2006;37:233-243; Whetten-Goldstein et al. Civil liability, criminal law, and other policies and alcohol-related motor vehicle fatalities in the United States: 1984-1995. *Accid Anal Prev* 2000;32:723-33; Williams AF, Zador PL, Harris SS, Karpf RS. The effect of raising the legal minimum drinking age on involvement in fatal crashes. *J Legal Stud*. 1983 Jan;12(1):169-179; Deshapriya EB, Iwase N. Impact of the 1970 Legal BAC 0.05 mg% limit legislation on drunk-driver-involved traffic fatalities, accidents, and DWI in Japan. *Subst Use Misuse*. 1998;33(14):2757-2788

24. Wagenaar AC, Maldonado-Molina MM. Effects of drivers' license suspension policies on alcohol-related crash involvement: long-term follow-up in forty-six states. *Alcohol Clin Exp Res*. 2007 Aug.;31(8):1399-1406; Rogers PN. The general deterrent impact of California's 0.08% blood alcohol concentration limit and administrative per se license suspension laws. An evaluation of the effectiveness of California's 0.08% blood alcohol concentration and administrative per se license suspension laws, Volume 1. Sacramento, California: California Department of Motor Vehicles, Research and Development Section. CAL-DMV-RSS-95-158; 1995; McArthur DL, Kraus JF. The specific deterrence of administrative per se laws in reducing drunk driving recidivism. *Am J Prev Med*.

challenging. The difficulty is compounded in the case of drunk driving laws by the incapacitating nature of the penalties involved which, as note above, can cloud the true size and nature of the deterrent effect.

BAC and pre-conviction license suspension laws aside, the evidence for general deterrence from drunk driving laws is variable. Evans et al²⁵ found no reduction in accident risk in the US from escalations in the drunk driving penalties, nor did Briscoe²⁶ in Australia. Wagenaar et al²⁷ identified a modest negative association between mandatory minimum fines for drunk driving and fatal crash rates, but the effects were not consistent across the 32 US states examined; this study also found no strong deterrent effects from mandatory minimum jail policies. On the whole, international reviews of general deterrence have concluded that traffic laws that promise increased certainty of punishment lead to temporary reductions in alcohol-related fatalities, whereas laws aimed at increased severity are ineffective.²⁸

Outside the drunk driving context, there is limited evidence on the general deterrent effects of traffic laws. What published studies exist are mostly positive. For example, Bar-Ilan and Sacerdote²⁹ found that red-light running in San Francisco and Israel decreased in response to an increase in the applicable fine. In Portugal, Tavares et al found that fine increases and the introduction of an “on-the-spot” fine payment policy were associated with decreases in both accident and injury rates.³⁰ The introduction of a penalty points system in Italy in 2003 was associated with reductions in both crashes and fatalities there.³¹ And Canadian laws aimed at stopping street racing and stunt driving have been linked to a small but significant reduction in speeding-related casualties among male drivers.³²

1999;16(1):68-75; Klein TM. Changes in alcohol-involved fatal crashes associated with tougher state alcohol legislation. Washington, DC: US Department of Transportation, National Highway Safety Administration. DOT HS 807 511; 1989; Zador P, Lund AK, Fields M, Weinberg K. Fatal crash involvement and laws against alcohol-impaired driving. Washington, DC: Insurance Institute for Highway Safety; 1988.

25. Evans WN, Neville D, Graham JD. General deterrence of drunk driving: evaluation of recent American policies. *Risk Anal.* 1991;11(2):279-289

26. Briscoe S. Raising the bar: can increased statutory penalties deter drink-drivers? *Accid Anal Prev.* 2004;36(5):919-929.

27. Wagenaar AC, Maldonado-Molina MM, Erickson DJ, Ma L, Tobler AL, Komro KA. General deterrence effects of U.S. statutory DUI fine and jail penalties: long-term follow-up in 32 states. *Accid Anal Prev.* 2007;39:982-994.

28. Ross HL. *Detering the drinking driver: legal policies and social control.* Lexington, MA: Lexington Books, 1980; Homel R. *Policing and Punishing the Drinking Driver. A Study of General and Specific Deterrence.* New York: Springer, 1988; Nagin DS, Pogarsky G. Beyond Stafford and Warr’s reconceptualization of deterrence: personal and vicarious experiences, impulsivity, and offending behaviors. *J Res Crime Delinq* 2001;39:153-186.

29. Bar-Ilan A, Sacerdote B. The response of criminals and noncriminals to fines. *J Law Econ.* 2004 April;47(1):1-17.

30. Tavares AF, Mendes SM, Costa CS. The impact of deterrence policies on reckless driving: the case of Portugal. *Eur J Crim Policy Res.* 2008;14:417-429.

31. De Paola M, Scoppa V, Falcone M. The deterrent effects of the penalty point system for driving offenses: a regression discontinuity approach. *Empir Econ.* 2013;45:965-985.

32. Meirambayeva A, Vingilis E, McLeod AI, Elzohairy Y, Xiao J, Zou G, Lai Y. Road safety impact of Ontario street racing and stunt driving law. *Accid Anal Prev.* 2014;71:72-81.

Specific deterrence

Drunk driving studies also dominate the specific deterrence literature. The standard approach here is to compare the effects of different forms and levels of punishment on recidivism.³³ The evidence is somewhat mixed. A few studies have detected significant specific deterrent effects,³⁴ but most have found no effects, very small effects, or effects only in discrete subpopulations (e.g. first-time offenders).³⁵

Two studies are noteworthy for extending specific deterrence investigations beyond the drunk driving context. Both reported evidence of specific deterrence. Li et al³⁶ examined a cohort of nearly 30,000 Maryland drivers who were ticketed for speeding. The researchers found lower risks of subsequent speeding citations but higher risks of crashes among drivers who elected to appear in traffic court, compared with drivers who chose to simply mail in payment of their fines. Among court-goers, those whose case was not prosecuted or suspended had significantly lower rates of subsequent crashing and reoffending than drivers with other case outcomes.³⁷

Redelmeier et al³⁸ studied a sample of drivers in Ontario, Canada, who were convicted of a wide range of traffic offenses. The drivers' risks of having fatal crashes in the month after a conviction were about 35% lower than in another comparable period; 2 months after the conviction this "benefit" had dwindled, and by 3-4 months it was no longer significantly different from the drivers' baseline risks. These results suggested a short-run specific deterrent effect.

33. Salzberg PM, Paulsrude SP. An evaluation of Washington's driving while intoxicated law: Effect on drunk driving recidivism. *J Safety Res.* 1984;15(3):117-124; Yu J. Punishment celerity and severity: testing a specific deterrence model on drunk driving recidivism. *J Crim Justice.* 1994;22(4):355-366; Taxman FS, Piquero A. On preventing drunk driving recidivism: an examination of rehabilitation and punishment approaches. *J Crim Justice.* 1998;26(2):129-143; McArthur DL, Kraus JF. The specific deterrence of administrative per se laws in reducing drunk driving recidivism. *Am J Prev Med.* 1999;16(1):68-75; Briscoe S, New South Wales, Bureau of Crime Statistics and Research. The impact of increased drink-driving penalties on recidivism rates in NSW. Bureau of Crime Statistics and Research. 2004;5:11; Weatherburn D, Moffatt S. The specific deterrent effect of higher fines on drunk-driving offenders. *Br J Criminol.* 2011;51(5):789-803; Ahlin EM, Zador PL, Rauch WJ, Howard JM, Duncan GD. First-time DWI offenders are at risk of recidivating regardless of sanctions imposed. *J Crim Justice.* 2011;39(2):137-142.

34. Yu et al 1994; McArthur et al 1999

35. Taxman and Piquero 1998; Salzberg and Paulsrude 1984; Ahlin et al 2011; Weatherburn and Moffatt 2011; Briscoe 2004.

36. Li J, Amr S, Braver ER, Langenberg P, Zhan M, Smith GS, Dischinger PC. Are current law enforcement strategies associated with a lower risk of repeat speeding citations and crash involvement? A longitudinal study of speeding Maryland drivers. *Ann Epidemiol.* 2011;21(9):641-647.

37. The investigators compared drivers in four outcome groups: (1) not guilty; (2) suspended/no prosecution; (3) probation before judgment and fines; and (4) fines and demerit points.

38. Redelmeier DA, Tibshirani RJ, Evans L. Traffic-law enforcement and risk of death from motor-vehicle accidents: case-crossover study. *Lancet* 2003; 361: 2177-2182.

IV. THE CAUSAL INFERENCE CHALLENGE

Known unknowns and unknown unknowns

The causal relationship between traffic laws and road safety is nuanced and challenging to isolate. Several inter-related factors conspire to complicate causal inference. One is that penalties do not occur in isolation; they are one of a host of variables that influence a driver's risk of crashing. Another complication is the well-established association (as distinct from causal relationship) between offenses and accidents: numerous studies have shown that drivers at high risk of incurring traffic citations are also at relatively high risk of crashing.³⁹

A more general way of describing these causal inference problems is to say that differences *between* drivers that influence both their risks of offending and their risks of crashing—and thus modulate the effects of penalties on driving behavior—cannot be fully observed and adjusted for, at least not in large population-level studies. Such “confounders” undercut researchers' ability to make strong causal claims about the effect of penalties on rates of accidents and recidivism.

Two of the most important between-person differences that usually cannot be observed in population-based studies are driving “exposure” (how much and when a driver is on the road) and driving performance (how safely a driver drives relative to others). A simple example helps to illustrate the problem. Imagine a driver who commutes to work and averages 100 kilometers of driving per day; she incurs two citations per year on average and crashes twice over a 10-year period. Another driver, who works at home and drives 10 kilometers per day, averages one citation per year and is involved in one crash over a decade. A comparison of the 10-year track records of these two drivers, based only on information about their offense and crash histories, would draw the specious conclusion that citations increase crash risk.⁴⁰

A range of other unobserved differences besides driving exposure have the potential to bias estimates of the causal effects of traffic law penalties. In interpreting results from their study of specific deterrence among Maryland speeders, for example, Li et al concede that “[t]he increased risk of crashes associated with court appearances likely reflects the high-risk characteristics of drivers who chose this approach rather than being a true causal relationship.” In sum, problems of unobserved heterogeneity bedevil large-scale studies that rely on unadjusted or under-adjusted comparisons of

39. See, for e.g., Gebers MA. An inventory of California driver accident risk factors. Technical report; California Department of Motor Vehicles: 2003; Blows S, Ameratunga S, Ivers RQ, Lo SK, Norton R. Risky driving habits and motor vehicle driver injury. *Accident Analysis and Prevention* 2005; 37: 619–624; DeYoung DJ, Gebers MA. An examination of the characteristics and traffic risks of drivers suspended/revoked for different reasons. *J Safety Res.* 2004;35(3):287-295.

40. A number of the studies of the deterrent effects of traffic laws make an inferential leap not unlike this.

different classes of offenders⁴¹—which is to say all but a couple of the specific deterrence studies conducted to date.

Attempts at stronger causal inference

Two studies of the safety effects of traffic laws were carefully designed to try to combat potential confounding bias. The studies reached opposite conclusions about whether penalties specifically deterred, although they were focused on different types of offenses.

Weatherburn and Moffat’s analysis of the specific deterrent effects of high fines on recidivist drunk driving exploited a quirk in the management of these cases in the New South Wales court system. The cases were assigned randomly within a panel of magistrates, yet court records showed wide variation in the severity of the penalties the magistrates imposed on offenders. The researchers took advantage of this variation to measure the effect of different penalty levels on recidivism. They detected no evidence of specific deterrence. Offenders who received more severe penalties did not have lower rates of recidivism.

In the Ontario study discussed above, Redelmeier, Tibshirani, and Evans made creative use of a case-crossover design to estimate the effect of convictions for a range of different traffic offenses on crash risk. In the case-crossover design, each case serves as its own control. All drivers in the study sample were involved in a fatal crash. The researchers compared each driver’s probability of incurring a penalty in the month before the crash with the probability that driver incurred a penalty in the same month one year earlier (when they did not crash). A lower penalty risk in the pre-crash period was interpreted as evidence of specific deterrence. The researchers found such an effect, albeit a transient one.

Although these two studies had very different designs, focused on different offenses or measures of safety, and reached opposite conclusions regarding specific deterrence, their methodologies were shaped by the a common goal: to counteract the threat of biases from unobserved between-driver differences. We shared this goal, and pursued it through a novel study design.

Overview of study approach

We exploited a “wrinkle in time” created by the way drivers are notified of certain offenses in Queensland. We followed a large cohort of drivers who were caught speeding or red-light running by traffic cameras. The drivers did not learn of their offense and the penalty to be imposed until 2-3 weeks after the offense occurred. We compared crash and offending rates in the periods immediately before and after the drivers received notification.

41. Nagin D, Cullen FT, Jonson CL. Imprisonment and reoffending. In Tonry M (ed.), *Crime and Justice: A review of Research*, 115-200. Chicago: Univ Chic Press 2009; Weatherburn and Moffat 2011.

This approach addresses the potentially pernicious effects of unobserved heterogeneity in two main ways. First, the comparison is between crash risk for a cohort of drivers immediately before and immediately after notification. The pre and post groups are homogeneous because they contain the same drivers (barring small losses for drivers who are censored because they crash or reoffend). Second, because the date of notification is determined by the regulator’s internal processes and the variability of the postal service, both of which are beyond the influence of drivers, it is difficult to imagine any connection, unrelated to specific deterrence, yielding an instantaneous change in drivers’ risk profile precisely at notification.⁴²

We turn to now to describe the methods in more detail.

V. STUDY APPROACH

Setting

With 4.8 million residents, Queensland is the third most populous state in Australia.⁴³ Its regime for driver licensing and regulation is broadly similar to Australia’s other states and territories, and to regimes in many other developed countries, including those currently in force in US states.⁴⁴ Queensland operates a graduated licensing scheme. Residents 17 years or older may apply for a learner license. Learners who log 100 hours of supervised driving, are at least 18 years of age, and pass both a written road rules test and a practical driving test are issued a provisional license. Provisional license holders become eligible for an “open” general license after one to three years.

Offenses and penalties

In Queensland’s penalty scheme, each traffic offense triggers a fine and carries a specified number of demerit points. Fine amounts vary widely, from around one hundred dollars for minor infractions to several thousand for the most serious ones. In 2014, the lowest speeding fine for first time offenders was \$AU151 and the highest was \$AU1,062.⁴⁵ The demerit points assigned to each offense are codified by statute, and range from 1 point for minor transgressions (e.g. failure to dip high-beam headlights for oncoming traffic, a small defect that renders the vehicle unroadworthy but not necessarily unsafe) to 8 points for exceeding the speed limit by more than 40 kilometres per hour. One-point and three-point offenses are by far the most common: they account for approximately 30% and 45%, respectively, of all citations issued.

42. As well as tackling unobserved between-driver differences, the short time-frame of our regression discontinuity design also addresses within-driver differences that may emerge over time, provided any such differences do not arise instantaneously at notification.

43. Australian Bureau of Statistics. *Australian Demographic Statistics*. Canberra: 2013.

44. Transport Operations (Road Use Management—Driver Licensing) Regulation 2010 (Queensland, Australia).

45. The Australian dollar is roughly equivalent in value to the US dollar.

The Queensland Department of Transport and Main Roads (DTMR) keeps a running tally of cumulative demerit points against every licensed driver in the state. Demerit points are removed three years after the offense, and fully reset after a period of license suspension or good driving behaviour.⁴⁶ Drivers who accumulate 12 or more demerit points in a three-year period typically face a period of license suspension of 3-6 months. Drunk driving offenses occupy a category of their own; they result in fines but not demerit points as such, because they almost always trigger a license suspension that is applied independently of the demerit point scheme.

Offenses are detected through a combination of direct observation by police and fixed and mobile traffic enforcement cameras.⁴⁷ Cameras are used in the detection of only two types of offenses: speeding and red-light violations.⁴⁸ For directly-observed offenses, police issue tickets at the roadside.⁴⁹ Camera-detected offenses are notified by mail. Over the time period of our study in Queensland, about half of all speeding and red-light offenses were detected by direct observation and half were detected by camera.

Data and variables

DTMR routinely collects details of both traffic offenses and crashes. Accurate tracking of offenses and penalties is essential for the operation of the state's demerit point system. All crashes that cause death, injury or substantial property damage are recorded, provided they are reported to the Queensland Police Service.⁵⁰

DTMR provided us with de-identified offense and crash data spanning the period 2 November 1996 to 31 December 2010. It also provided de-identified license histories for all drivers in Queensland over the same period; for each driver, this included dates when the driver was licensed and, if applicable, dates when the license was suspended or disqualified.

Using de-identified numbers unique to each licensee, we linked the infringement, crash and license history data to create the study dataset. The dataset included variables describing drivers (age, sex), crashes (severity, fault), and offenses (type, number of demerit points). Our offense typology was based on categories set

46. When Queensland drivers reach 12 demerit points, they are given a choice of accepting a suspension for a relatively short period (usually 3 months) or continuing to drive under threat of heavier suspension (usually 6 months) if one further offense occurs during a defined period of good driving behaviour (usually 12 months). Our data allowed us to observe these choices and drivers were excluded from our analysis for any periods in which their license was suspended.

47. State Penalties and Enforcement Act 1999 (Queensland, Australia).

48. Transport Operations (Road Use Management) Act 1995 (Queensland, Australia), s 13, 158.

49. Colloquially, these are referred to as "on-the-spot" tickets.

50. The "substantial" property damage threshold is met if at least one vehicle is towed away, the cost of damage to all property exceeds \$2,500 (before December 1999), or the cost of damage to property other than vehicles exceeds \$2,500 (from December 1999). See Queensland Department of Transport and Main Roads. *Data Analysis: Road crash glossary*. Available at <https://www.webcrash.transport.qld.gov.au/webcrash2/external/daupage/docs/glossary.pdf> (accessed 10 Sept 2014).

forth in the Australian and New Zealand Offense Classification.⁵¹ We also constructed measures of the cumulative number of demerit points each licensed driver had at successive points in time.

DTMR uses five mutually-exclusive categories to describe crash severity: (1) fatality; (2) injury requiring hospitalization; (3) injury requiring medical treatment but not hospitalization; (4) injury not requiring medical treatment; and (5) property damage only. We collapsed these into a binary variable indicating “serious or fatal injury” (first three categories) and “minor or no injury” (last two categories). Of course, many crashes involve multiple injuries and property damage. The variable we used pertains to the most serious outcome in each crash.

Determinations of fault for each crash, including single vehicle collisions, are made by DTMR on the basis of the police report. The “at fault” designation is applied to the person judged to be most at fault, and to any persons issued with traffic citations in connection with the crash.

Study design

We used a regression discontinuity design to compare the two outcome variables of interest—crash rates and recidivism rates—across two time periods.⁵² This is a quasi-experimental design that permits causal inference in wide variety of situations. The design requires that experimental units are assigned to treatment on the basis of threshold defined by a covariate that takes values on a continuum. If the only difference between experimental units immediately on either side of the threshold is the fact of the treatment, then any discontinuity arising at the threshold must be linked causally to treatment.⁵³ In our analysis, the continuous measure is time and the threshold is defined by the moment at which offending drivers were notified that their violation had been caught on camera and that penalties were being imposed.⁵⁴ Specific deterrence theory suggests that drivers’ risks of both offenses and crashes should decrease from that moment forward.

51. Australian Bureau of Statistics. Australian and New Zealand Offense Classification 2011 (3rd edition).

52. On one view, it is somewhat unorthodox to conceive of time as the continuous measure for assortment in a regression discontinuity design. However, previous studies with designs in the regression discontinuity family have used attainment of a certain age to “switch on” treatment status (see studies reviewed in David S. Lee and Thomas Lemieux, Regression discontinuity designs in economics. NBER Working Paper No. 14723 (February 2009). It is also true that our approach also has many of the basic features of an interrupted time series design (see Penfold RB, Zhang F. Use of interrupted time series in evaluating health care quality improvements. *Acta Pediatr.* 2013;13(6 Suppl):S38-44). We believe these are largely distinctions in labels, which do not have a substantive bearing on the nature or appropriateness of the design we implemented.

53. Thistlethwaite DA, Campbell DT. Regression-discontinuity analysis: An alternative to the ex post facto experiment. *Journal of Educational Psychology* 1960;51(6):309-317; Imbens G, Lemieux, T. Regression discontinuity designs: a guide to practice. *Journal of Econometrics* 2008;142:615–635

54. If notification and infringement occur on the same day then causal inference from a regression discontinuity design is not possible because drivers who experience crashes are much less likely to go on to commit offenses (because, for example, their car is off the road being repaired), so any discontinuity must be interpreted as the sum of the extent to which crashes prevent subsequent offenses and the deterrent effect of the penalty associated with the offense.

Construction of the two time periods requires further explanation. The first time period consisted of an interval running from the day a driver committed a camera-detected offense to a day near the moment when the driver received notification of the offense and the applicable penalty. We refer to this interval as the “pre-notification period”. We set an upper limit of 21 days on the pre-notification period. The second time period, the “post-notification period”, ran for 90 days following notification.

One complication with construction of the discontinuity in our study is that we did not know the exact date drivers became aware of their offense. Our data included a variable indicating the date the offense was registered by DTMR; as a matter of routine practice, this date is one business day before the DTMR generates the notification letter.⁵⁵ The letter is sent by regular post, which typically takes 1-2 days, but the letter may not be opened and read by the offender immediately. Further, although licensees are obligated by law to notify DTMR within 14 days of any change of name or address, not all do, and some letters are sent to the wrong address or wrong person.

To address this fuzziness around the day of the offender’s first awareness, we created a “notification week”. Specifically, for each offense we calculated a best-estimate date, defined as the date three business days (i.e. exclusive of weekends and public holidays) after the date DTMR registered the offense. The notification week was calculated by counting three days forward and three days back from the best-estimate day. Thus, the pre-notification period actually ended on the fourth day before the best-estimate day and the post-notification period began on the fourth day after the best-estimate day. Some misclassification across time periods is inevitable, and its effect would be to bias any true differences between the periods to the null. However, we believe it is safe to assume that the vast majority of drivers in our sample would have become aware of their offense and penalty during the notification week.

Study sample

Drivers who committed camera-detected offenses entered the study sample, provided they were at least 20 years of age⁵⁶ and their license remained active throughout the

55. Telephone conversation of July 23, 2014 with Dr. Nerida Leal, Principal Behavioural Scientist, Queensland Department of Transport and Main Roads.

56. Drivers with learner and provisional licenses must comply with special rules that do not apply to other drivers. For example, learners must drive under supervision; provisional license holders have certain restrictions on carrying passengers, driving high-powered vehicles, and driving at night, and the demerit point threshold for license disqualification is lower than for drivers with open licenses. Hence, to avoid complications in the analysis and in interpretation of findings, we sought to exclude learners and provisional license holders from the study sample. The difficulty was that we did not have information that allowed us to identify these drivers directly. Therefore, we used age as a proxy, excluding all drivers under 20 years of age. This undoubtedly produced errors: Queenslanders as young as 19 obtain unrestricted open licenses, and some learners and provisional drivers are over 20 years of age. However, the overwhelming majority of learner and provisional drivers are under 20, and

study period. We observed this “cohort” for 112 days—21 days pre-notification, the day of notification, plus 90 days post-notification.⁵⁷ However, the cohort’s membership was not completely fixed; it changed in two ways over the observation window.

First, we allowed for different lag periods between the offense and notification. Any driver whose lag period was 22 days or more entered on the first day of the pre-notification period; the rest joined on the day after their index offense.

Second, drivers who crashed or re-offended were censored from the cohort immediately after counting those events in the daily rate. There was a strong reason to do this for drivers who crashed: the crash reduced the likelihood they would continue driving for some or all of the remaining observation period, so retaining them would be likely to bias downwards the crash and offense rates calculated for subsequent days.⁵⁸ Re-offenders were censored because their response to any subsequent offense may have overlapped in time with their response to the index offense, thus blurring the deterrent effect under study. A countervailing consideration in the treatment of re-offenders is that, because offenses are such frequent events, our censoring rule served to eliminate nearly 15% of the cohort by the end of the post-notification period. Such attrition should not have affected the discontinuity effects, but it may have introduced some more general biases.⁵⁹

Statistical analysis

The main goal of the statistical analysis was to estimate the size and significance of the two discontinuities of interest—differences in crash risk and recidivism, respectively—between the pre- and post-notification periods. We fit a generalized additive regression model from the Poisson family with an offset to permit the estimation of rates rather than counts. Time trends in the crash and recidivism rates were modelled using thin plate splines. Other covariates were added to the model as parametric terms.⁶⁰

In the primary crash model, the outcome variable was crashes per 100,000 drivers per day; in the primary recidivism model, the outcome variable was offenses per 100,000 drivers per day. The covariates specified in these two models were essentially the same. The predictor of interest was a dummy variable distinguishing observations in the pre-notification period from observations in the post-notification

most drivers under 20 fall into one of these two license categories, so the age-based exclusion rule was a reasonable work-around.

57. Hereafter, when it is necessary to distinguish the camera-detected speeding or red light offense that brought drivers into the sample from subsequent offenses drivers committed, we refer to the former as the “index” or “notified” offense.

58. On the other hand, the fact that so few drivers crashed, relative to the size of the baseline population, means this bias would probably not be noticeable.

59. We describe this issue in more detail in the Discussion section.

60. Wood SN. Modelling and smoothing parameter estimation with multiple quadratic penalties. *Journal of the Royal Statistical Society (B)* 2000;62(2):413-428; Hastie TJ, Tibshirani RJ. Generalized additive models. Chapman & Hall/CRC, 1990.

period. The thin plate splines controlled for time trends within the pre- and post-notification periods. The models also included dummy variables marking the number of days from notification modulo 7 to account for a day-of-the-week effect.⁶¹ In addition, we adjusted for several covariates known to have an independent association with the outcomes of interest: driver age, offense type (red light, minor speeding, moderate speeding, major speeding), and cumulative demerit points. Inclusion of these baseline risk factors strengthened our ability to interpret the magnitude of the discontinuities as average effects at the population level.

Results of the primary crash and recidivism models are presented in two ways. We drew adjusted trend lines on either side of the discontinuity, and superimposed them on scatter plots of the raw daily rates. We also present coefficients and 95% confidence intervals from the models in tabular form.

The second step in our analysis was to determine whether there were subgroup differences in the size of the discontinuity effects estimated in the primary models. To do this we conducted a series of stratified analyses. The models had identical specifications to the primary models, but were run within defined subgroups of drivers.

For crash risk, we analysed the magnitude of the discontinuity within the following subgroups: (1) drivers for whom the notified offense brought their cumulative demerit point total near to the point of license disqualification (9-11 points) *versus* drivers who remained at a low point count after the notification (1-5 points); (2) crashes in which the driver was judged to be at fault *versus* not at fault; and (3) crashes that resulted in serious injury *versus* minor injury.

For recidivism risk, we estimated discontinuity effects within the following strata: (1) the same high-*versus*-low cumulative demerit point totals as described above for the crash risk analyses; (2) subsequent offenses detected by camera *versus* direct observation; (3) high-risk *versus* low-risk offenses;⁶² and (4) concordance between the type of index offense and the type of subsequent offense *versus* discordance in offense types.

All analyses were conducted in R (version 3.1.1).⁶³ Only a small fraction of the data was missing (<0.25% for all variables analysed).

61. We could not include day of the week directly because notification may have been made on any non-holiday weekday. Thus, a day that was 8 days from notification would assume the same value in this day-of-the-week variable as would the day that was one day from notification.

62. These two strata were created by separating offenses clearly indicative of risk driving behaviour (e.g. dangerous/careless driving, speeding, red-light running, line crossing, drunk driving, failure to wear a seatbelt or helmet, failure to give way, etc) from offenses not clearly related to risky driving (e.g. administrative non-compliance, unsafe carriage of goods, defective vehicle, public nuisance etc.).

63. R Core Team (2014). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria.

Ethics

The Human Research Ethics Committee at the University of Melbourne approved the study.

VI. RESULTS

Sample characteristics

Table 1 profiles characteristics of the drivers ($n=2,880,763$) in the study sample, together with the type of camera-detected offense that brought them into the sample. Sixty percent of the drivers were male and 64% were aged between 31 and 60 years. Ninety-one percent were caught speeding; the rest ran red lights. Two thirds of drivers had acquired fewer than six demerit points, inclusive of the points associated with the notified offense; at the other end of the spectrum, the notified offense brought 14% of drivers up to nine or more demerit points.

Table 2 shows the severity of crashes ($n=15,317$) that occurred during the study period. One percent caused at least one fatality, 22% caused injuries serious enough to require hospitalization, and 27% caused injuries that were treated outside hospital. Drivers in our sample were judged to be at fault in 62% of the crashes in which they were involved.

Table 3 describes the offenses ($n=184,544$) drivers committed during the 112-day observation period, following their index camera-detected offense.⁶⁴ Seventy-one percent of the re-offending involved speeding. The next most prevalent types of offenses were red light violations (4%), driving while uninsured or unregistered (3%), and using a mobile phone while driving (2%). Fifty-three percent of the offenses were detected by camera and 47% by direct police observation.

Effects of notification on crashes

Notification did not lead to a significant change in drivers' risks of crashing (Rate Ratio [RR], 0.94; 95% Confidence Interval [CI], 0.86-1.02) (**Figure 2**).

Table 4 shows the full set of estimates from the multivariate regression model. Drivers' age, gender, and cumulative demerit point total were all significant predictors of crash risk, as was the type of camera-detected offense committed, but notification was not.

This result was robust across all subgroups examined (**Figure 3**). Drivers for whom the notified offense took their cumulative demerit point tally into the range of 9-11 points, the level at which one further offense would likely result in license disqualification, did not exhibit a significant change in crash risk following notification (RR, 1.31; 95% CI, 0.91-1.87). Nor did we detect a significant change in

64. These figures do not represent a full accounting of the reoffending by drivers in our cohort during the 112-day period. Because we treated re-offending as a censoring event, we did not analyze and do not report in Table 3 any further offenses (third, fourth, fifth, etc.) by drivers who committed more than two offenses.

crash risk when the analysis was restricted to drivers at fault in the crash (RR=0.93; 95% CI, 0.87-1.01), or to crashes that caused fatal or serious injury (RR, 0.97; 95% CI, 0.85-1.10).

Effects of notification on recidivism

The rate at which drivers committed offenses decreased by 25% immediately after notification (RR, 0.75; 95% CI, 0.73-0.78) (**Figure 4**), and remained relatively low for the remainder of the post-notification period.

Table 5 shows the full regression results. The baseline predictors for recidivism ran in the same direction and were of a similar magnitude as in the crash model, except for offense type. Speeders reoffended at a higher rate than red light runners, but they crashed at a lower rate.

The decrease in recidivism following notification varied within several of the subgroups of drivers examined (**Figure 5**). The decrease in rates of offenses clearly indicative of risky driving (RR, 0.70; 95% CI, 0.69–0.72) was larger than the decrease observed in rates of low-risk offenses (RR, 0.78; 95% CI, 0.73–0.83).⁶⁵ There was a larger decrease in camera-detected offenses following notification (RR, 0.68; 95% CI, 0.66-0.70) than there was in offenses detected by direct police observation (RR, 0.75; 95% CI, 0.73-0.77).

Drivers whose index offense was a camera-detected red light violation had rates of red light violation after notification that were 41% lower (RR=0.59, 95% CI, 0.49-0.72). Drivers whose notified offense was speeding had rates of speeding re-offending that were 31% lower (RR=0.69, 95% CI, 0.67-0.71). By contrast, rates of reoffending by offenses of a different type to the notified offense were “only” 23% lower after notification (RR=0.77, 95% CI, 0.74-0.80).

On the other hand, the magnitude of the decline in recidivism was insensitive to drivers’ demerit point tallies. Drivers whose notified offense took them into the 9-11 point range decreased their offending rates (RR=0.69, 95% CI, 0.65-0.73) by about the same amount as drivers whose notified offense did not take their cumulative demerit point above 5 points (RR=0.71, 95% CI, 0.69-0.73).

VII. DISCUSSION

This study followed a cohort of drivers who had broken road rules and been caught. We followed them from the time they committed a speeding or red-light offense, through the time they were informed that they had been caught and would be penalized, and then for three months afterwards. We found that notification did not reduce the likelihood of subsequent crashes, even among drivers for whom another offense probably spelled license suspension.

65. For a description of which offenses went into which categories, and the basis for the classifications, see *supra* note 62.

The notification did, however, result in a substantial reduction in drivers' risks of committing additional offenses. Subgroup analyses shed further light on this effect. There was an especially large reduction in offenses of the same type as the notified offense, suggesting a kind of specific-specific deterrence at work. Similarly, notification reduced the incidence of offenses indicative of risky driving choices more than it did the incidence of offenses that were more administrative or technical in nature. In other words, behaviours that were relatively dangerous and which ostensibly fell more directly under the drivers' control decreased by a larger amount. This is a plausible result within a deterrence framework.

Set alongside each other, the effects we observed on crash risk and recidivism raise two obvious questions. First, if deterrence theory rests on the assumption that curbing offending prevents accidents, how does one happen without the other? Second, should one infer from our findings that traffic laws in Queensland are producing an effective form of specific deterrence? We consider each of these questions in turn.

The bifurcation of specific deterrence

Pure avoidance behaviour

One way in which recidivism could decline without moving the needle on crash rates is through avoidance behaviour. Notification may have prompted drivers to alter their driving behaviour in ways that substantially reduced their risk of incurring additional penalties but which did not materially affect their crash risk. Imagine a driver who is motivated to steer clear of intersections he knows have cameras, or avoid stretches of road he knows are a common speed trap. These moves could be made without necessarily changing the care with which he drove.

One of the subgroup analyses provides some indirect support for an avoidance explanation. The rate of camera-detected offenses dropped more sharply after notification than did the rate of offenses ticketed at the roadside.⁶⁶ Mobile enforcement by police has a stochastic dimension that probably makes it more difficult than cameras to thwart, in the absence of authentic changes to the safety with which one drives. In sum, behavioural responses focused on pure enforcement evasion could drive a wedge between risks of recidivism and risks of crashing.

Relationship between offending and crash risk

A more fundamental and damning explanation for the bifurcation is that offending behaviour—or more precisely, offending behaviour that law enforcement catches—has a weak connection to crash risk at the population level. Regulators and safety experts like to focus on the strength of the connection, emphasizing, for example, that the behaviours traffic law regimes sanction are associated with crash risk, and that multi-offenders have higher crash risks than occasional or never

⁶⁶ Recall that all cohort members entered on camera-detected offenses, but the daily rates reported in the recidivism model relate to both camera detected and directly observed offenses.

offenders.⁶⁷ But widening the frame, the reality is that the strength of the relationship is diluted at several critical nodes. Cameras and police capture only a small fraction of offenders. Crashes are rare events (much rarer than penalties.) And many crashes are not attributable to unlawful behaviours, although a sizeable proportion appears to be.⁶⁸

Each of these factors weakens the relationship between the incidence of offending behaviour and crashes at the population level.⁶⁹ The sinews are probably loose enough to permit offending rates within a defined population to decrease or increase across a fairly large range without altering crash rates. This theory does not explain why, in our study, recidivism was deterred and crashes were not, but it explains how the two effects can coexist.

Is specific deterrence working in Queensland?

Unlike some other realms of law—much of criminal law, for example—traffic laws face a separation between the bad act and the bad outcome. The regime is oriented almost entirely to certain bad acts—specifically, it penalizes bad acts known or believed to be associated with bad outcomes (i.e. crashes, injury, and property damage). The bad outcome need not materialize in a given case for the penalty to apply—indeed it rarely does.⁷⁰ Our results throw this separation between act and outcome into sharp relief. This poses an interesting quandary for specific deterrence.

Tort scholars tend to focus primarily on behaviour change as the principal target for deterrence. At one level, this is sensible. The causes of crashes are multifactorial and the driver carelessness is just one factor. So surely the law should not be judged by its capacity to curtail dangers over which it has little or no control. Nonetheless, honouring the focus on behavioural change might lead one to conclude that Queensland's traffic laws are performing admirably as a specific deterrent.

From a broader public health and policy standpoint, however, the suggestion that a legal regime could be regarded as performing successfully for having curbed a surrogate of the bad outcome, without having any measurable effect on the outcome

67. See, for e.g., Gebers MA. An inventory of California driver accident risk factors. Technical report; California Department of Motor Vehicles: 2003

68. It is difficult to find statistics to quantify this split. Data from the National Highway Transportation Safety Agency indicate that in 2012 31 percent of all road fatalities (n=10,322) were due to alcohol-impaired driving and 31 percent of all fatalities (n=10,219) were due to speeding. Red light runners are apparently responsible for 2% of fatalities and 7% of injuries. But there is undoubtedly overlap between these various groups, and the representation of other types of offending behaviours in crashes is not readily available.

69. The weakness of the relationship also helps to explain why it has proven infeasible to predict the incidence of crashes at the population level on the basis drivers' offense records. Some studies have shown a significant relationship between infringement and crash histories (see, for e.g., Geber MA, Peck RC. Using traffic conviction correlates to identify high accident-risk drivers. *Accident Analysis and Prevention* 2003;35:903-912). But correlation and prediction are different beasts. No study has shown offense data can predict crashes with levels of accuracy that are high enough to justify aggressive interventions in high risk populations of drivers.

70. The obvious exception is citations triggered by the behaviour of a driver who has crashed, but these represent only a small fraction of all citations issued.

itself, is somewhat absurd. Traffic safety regulators do not proclaim to sanction unlawful driving as an end in itself; they sanction it to prevent harm. We did not find evidence of such prevention.

One caveat to that conclusion is that there may have been some true reduction in crashes that we could not detect. The risk ratio for the notification variable in the primary crash risk analysis was 0.94. Although the estimate was not statistically significant at conventional levels, the relative rarity of crashes meant this analysis was not nearly as highly powered as the recidivism analysis. If it had been statistically significant, a reduction in crash risk of this magnitude is not trivial. Depending on how much it cost, a community might very happily embrace a safety intervention that reduced crash risk by 6 percent.⁷¹

Other trends in levels risk over time

Although our analysis was designed to examine changes in crash and offending rates immediately after notification, two other patterns appeared repeatedly in the pre- and post-notification periods, and warrant discussion.

Increase in recidivism in the pre-notification period

The primary recidivism plot and most of the stratified recidivism analyses show a steep rise in penalty risk in the pre-notification period, peaking at or shortly before notification. What accounts for this uptick?

Recall that the period of time between the camera detected offense that marked drivers' entry into the cohort and the time at which they received notification of their offense varied considerably. Drivers with notification periods of three weeks or longer contributed to the daily rate calculations beginning on the first day of the pre-notification period. Others had notification periods of less than a week, which meant they would have contributed only to the rates in the few days before the notification week began.

If riskier drivers were more likely to have short notification periods, this might explain the upward-sloping curves we observed in the pre-notification period. We found some evidence to support this theory. For example, daily recidivism rates increased slightly less in the pre-notification period among drivers with characteristics normally associated with lower crash risks (e.g. female drivers, city dwellers, low-level offenders)

Why would high-risk drivers have systematically shorter notification periods? Two reasons seem plausible. First, DTMR may have pursued a practice of faster notification of drivers who appeared to be riskier, based either on the nature of the offense they had committed or their demographic profile. Second, offenders who, on average, took longer to reach may have had lower risks of reoffending than those who were reached more quickly. Drivers living in rural areas, for example, generally have

⁷¹ In the United States, a reduction of that size would equate to over 2,000 deaths and 100,000 injuries per year.

slower postal service than city dwellers, and intensity of enforcement in rural areas, particularly by cameras, is lower than in cities.

Decrease in crashes and recidivism in the post-notification period

Another noteworthy trend, not obviously related to the discontinuity of interest, is the steady decline in rates of both recidivism and crashes observed over the 90-day post-notification period. This is evident in nearly all of plots. One explanation is that the specific deterrent effect gains momentum gradually, possibly instigating a “learning curve” along which drivers move toward safer driving. This is a hopeful scenario, but a doubtful one. It cuts against several other studies that have found the opposite—namely, deterrent effects from traffic penalties tend to decay over a period of a few months.⁷²

The steady decreases in the post-notification period are more likely to be an artefact of a methodological limitation of our study. One problem that is more-or-less intrinsic to population-level road safety studies was discussed at length earlier—namely, lack of direct adjustment for driving behaviour. Drivers in our cohort were known to have been driving at the date of their offense,⁷³ but the extent of their presence on the road becomes less clear the further one moves in time past the offense date. Consequently, the declines in penalty and crash risk observed in the post-notification periods probably reflect a reduced exposure to driving.

There are a couple of further points to be made here. First, this exposure measurement problem should not materially affect our main findings.⁷⁴ The daily rates that matter most to our estimates are those close to the discontinuity. Second, if drivers *are* driving less in the post notification period, part of their motivation for doing so may be a desire to avoid further penalties. Reductions in risk that stem from such a response might legitimately be counted as part of a specific deterrent effect, not confounding.

Limitations

Our study has several limitations worth noting. First, the generalizability of our findings outside Queensland is unknown. Even within Queensland, it is unclear

72. See, for e.g., Homel 1988; Redelmeier et al 2003.

73. This is not strictly true. The citation is normally sent to the vehicle’s registered owner, and someone else may be been at the wheel the vehicle at the time of the camera detected offense. DTMR has a routine process for accepting challenges on “other driver” grounds. If the challenge is upheld, the penalty, together with any associated demerit points, are re-assigned to the actual offender. The offenders in our data are those to whom the penalty was ultimately assigned. Thus, our confidence that the offender was driver can be reasonably high, but some scope for misclassification still exists (e.g. a challenge is wrongly dismissed, a registered owner who did not offend does not challenge and “takes the hit” for someone else, drivers collude in some other way to shuffle penalties and demerit points between each other, etc.).

74. The same cannot be said of measurement of road safety risks using the case-crossover design, where this phenomenon creates, what epidemiologists refer to as, “confounding by indication”. This is a substantial and largely intractable problem in studies of this kind. See, Redelmeier et al 2003; Simon J. Walter and David M. Studdert, Relationship between penalties for road traffic infringements and crash risk in Queensland, Australia: A case-crossover study. *International J Epi* 2015;44:1722-30.

whether the cohort entry criterion—camera-detected speeding or red-light offenses—produced a sample of drivers whose subsequent behaviour differs from the universe of offenders.

Second, although we could guess with a fair degree of confidence at a date range within which offenders became aware of their penalty, we did not know with certainty. A non-trivial number of drivers in our sample of nearly three million will have learned of their penalty after the notification week. Penalty letters are not infrequently sent to the wrong address or the wrong person; people are away from their home address for extended periods; and some people defer opening their mail—perhaps especially if it has the hallmarks of bad news from the government!

Relatively few drivers are likely to have received their letters before the notification week. However, some may have known they offended and suspected they were caught at the time of the offense—alerted, for example, by the flash of a camera at night.⁷⁵

Whether actual awareness occurred before or after the notification week we specified, the effect on our results is probably the same: a bias to the null. Incidentally, using a notification week instead of a precise date should bias our results in the same direction.

Third, our decision to censor drivers who crashed or reoffended from the cohort was not ideal, but preferable to the alternative. Many crashes force drivers off the road for a period of time, so retaining them inflates the “at risk” population for an unknown number of subsequent days. Retaining offenders is problematic for a different reason: deterrent effects of the subsequent offense could become entangled with deterrent effects associated with the offense of interest.

There is no realistic possibility that removal of drivers who crashed affected our findings: there were far too few of them. By contrast, 2,000-3,000 drivers reoffended each day, and by the end of the observation period in the recidivism analysis, 14% of the sample had been censored. To explore whether this censoring affected our results, we re-ran the recidivism model without censoring recidivists. The results changed very little.

Finally, it would be inappropriate to infer from our findings that penalizing traffic offenses does not reduce crashes in Queensland. We did not consider the effects of general deterrence, and it may succeed where specific deterrence fails.

VIII. CONCLUSION

Traffic laws exist primarily to promote road safety. In a broad sense, “safety” refers to the care and competence with which people behave on and around the road. The

75. Some offenders photographed at night will have experienced camera flashes; others will not have, because many of the cameras in use during the study period were fitted with infrared technology.

two standard ways of measuring safety at the population level are rates of offending and rates of crashes; both are regularly used as proxies for unsafe driving.

Our results call into question some of the assumptions embedded in this practice. We found that offending rates dropped in Queensland following notification of an offense while crash rates were unmoved. This is a form of specific deterrence, but a hollow one.

The split finding also raises fundamental questions about what specific deterrence means and what traffic laws are accomplishing. Should recidivism be de-emphasized as a proxy for safety, and avoided as a measure of deterrence? Is Queensland's regime penalizing the wrong behaviours, or the right behaviours in the wrong way? Could better enforcement bridge the gap and produce real reductions in both recidivism and crash risk? And if true safety effects flow only from general deterrence, should specific deterrence goals be abandoned? Perhaps Queensland would be better off diverting resources from catching and penalizing drivers to publicity campaigns and showy displays of enforcement, in the interests of pursuing a form of deterrence that may work. Future research should address these questions in Queensland and consider them elsewhere. Important aspects of the logic and efficacy of traffic laws hinge on the answers.

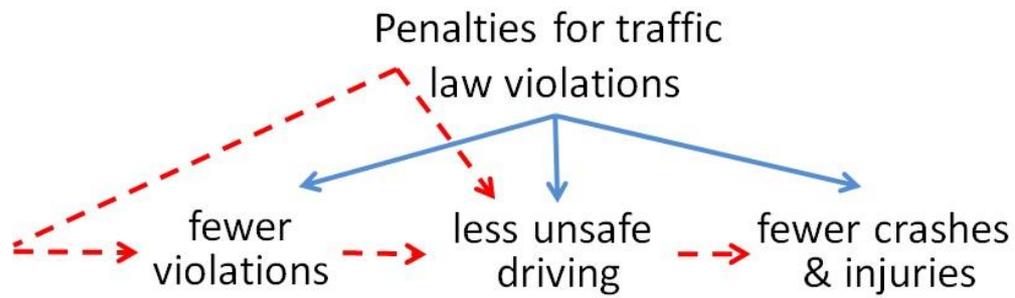
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Figure 1. Conceptual model of general and specific deterrent effects of traffic laws



Note: Solid blue lines indicate pathways for general deterrent effects. Dotted red lines indicate pathways for specific deterrent effects.

Table 1. Characteristics of drivers and index offenses in the study sample (n=2,880,763)

	<i>n</i>	%
Sex		
Male	1,736,971	60%
Female	1,143,792	40%
Age		
20-25 years	412,947	14%
26-30 years	364,480	13%
31-60 years	1,842,321	64%
>60 years	261,015	9%
Cumulative demerit point total		
<6 points	1,897,749	66%
6-8 points	572,804	20%
9-11 points	237,512	8%
>12 points	172,698	6%
Type of camera-detected offense		
Speeding	2,617,107	91%
Minor (0 or 1 points)*	1,417,839	49%
Moderate (3 points)	1,067,386	37%
Major (4+ points)	131,882	5%
Red light violation (3 points)	263,656	9%

* 823 speeding violations (0.03% of the sample) resulted in no demerit points.

Table 2. Characteristics of crashes that occurred during the study period (n=15,317)

	<i>n</i>	%
Severity		
Fatal	147	1%
Injury requiring hospitalization	3,300	22%
Injury requiring medical treatment outside hospital	4,068	27%
Injury not requiring medical treatment	2,295	15%
Property damage only	5,507	36%
Fault		
At fault	9,548	62%
Not at fault	5,769	38%

Table 3. Characteristics of offenses that occurred during study period, following the index camera-detected offense (n=184,544)*

	<i>n</i>	%
Type of offense		
Speeding	131,922	71%
- Minor	54,054	29%
- Moderate	62,413	34%
- Major	15,455	8%
Red light violation	7,966	4%
Uninsured or unregistered driving	4,860	3%
Use of mobile phone while driving	4,609	2%
Driving under influence of alcohol or drugs	4,571	2%
Illegal stop or park	3,956	2%
Failure to wear seatbelt or helmet	3,316	2%
Administrative non-compliance	2,425	1%
Defective vehicle	2,325	1%
Illegal turn	2,293	1%
Unlicensed driving	2,271	1%
Other failure to stop	2,155	1%
Violation of probationary driving rules	1,232	1%
Other	10,643	6%
Demerit points		
0	25,048	14%
1	57,150	31%
2	2,518	1%
3	84,373	46%
4+	15,455	8%
Mode of detection		
Camera	98,426	53%
Police observation	86,118	47%

* The table does not include the index camera-detected offenses that brought drivers into the study sample

Figure 2. Discontinuity in the crash rate

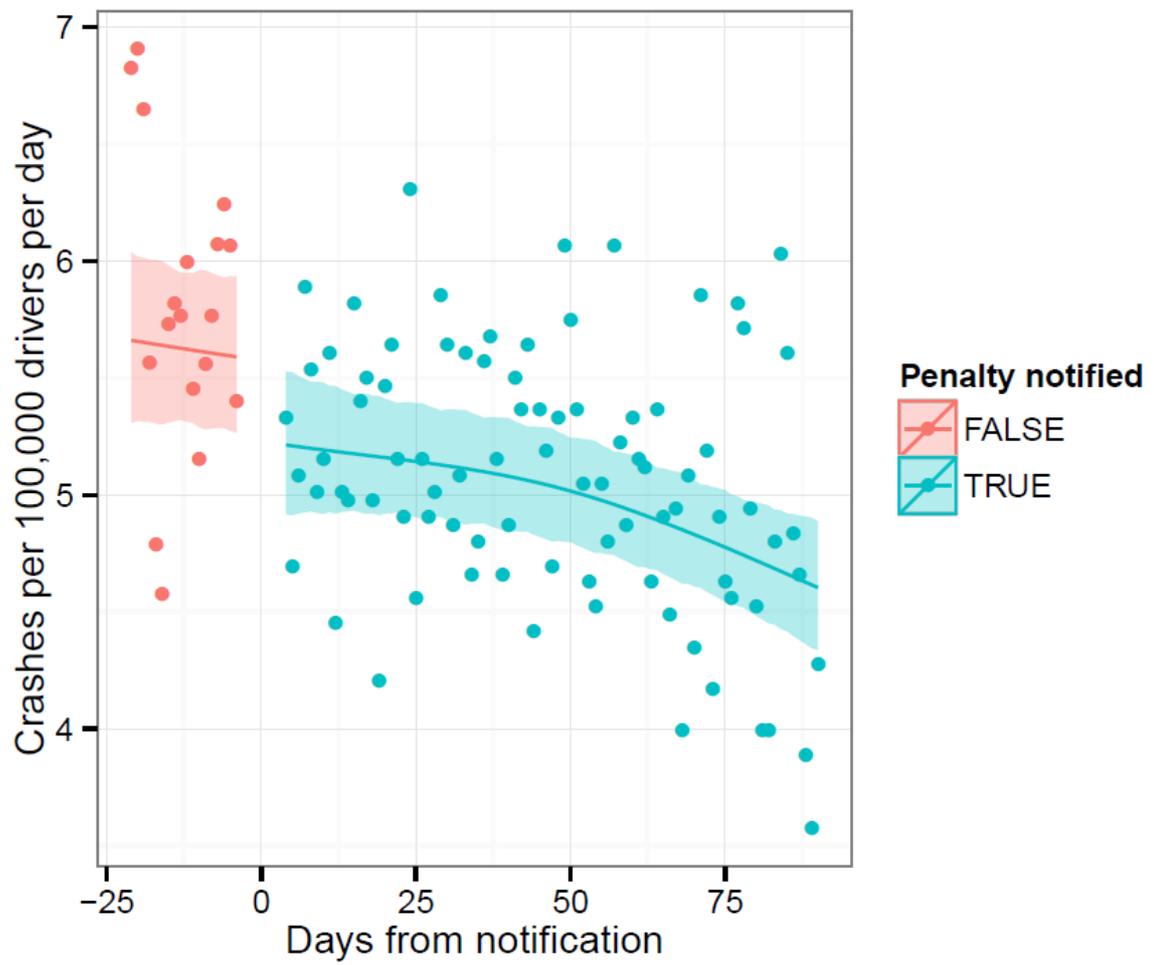


Table 4. Multivariate predictors of crashes*

	Rate ratio (95% CI)	P value
Notification	0.94 (0.86-1.02)	0.1384
Driver male (ref: Female)	1.31 (1.27-1.36)	<0.001
Driver age (ref: 20-25 years)		
26-30 years	0.73 (0.69-0.77)	<0.001
31-60 years	0.57 (0.55-0.59)	<0.001
>60 years	0.47 (0.44-0.51)	<0.001
Cumulative demerit points (ref: <5)		
5-8 points	1.37 (1.31-1.43)	<0.001
9-11 points	1.73 (1.64-1.82)	<0.001
>11 points	2.60 (2.47-2.74)	<0.001
Type of offense (ref: Red light violation)		
Speeding - minor	0.78 (0.74-0.82)	<0.001
Speeding - moderate	0.77 (0.73-0.81)	<0.001
Speeding - major	0.87 (0.81-0.94)	<0.001

* The model also included a smooth term to adjust for crash risk over time, and dummy variables indicating the number of days from notification modulo 7 to adjust for a day-of-week effect.

Figure 3. Discontinuities in crash rates within defined subgroups

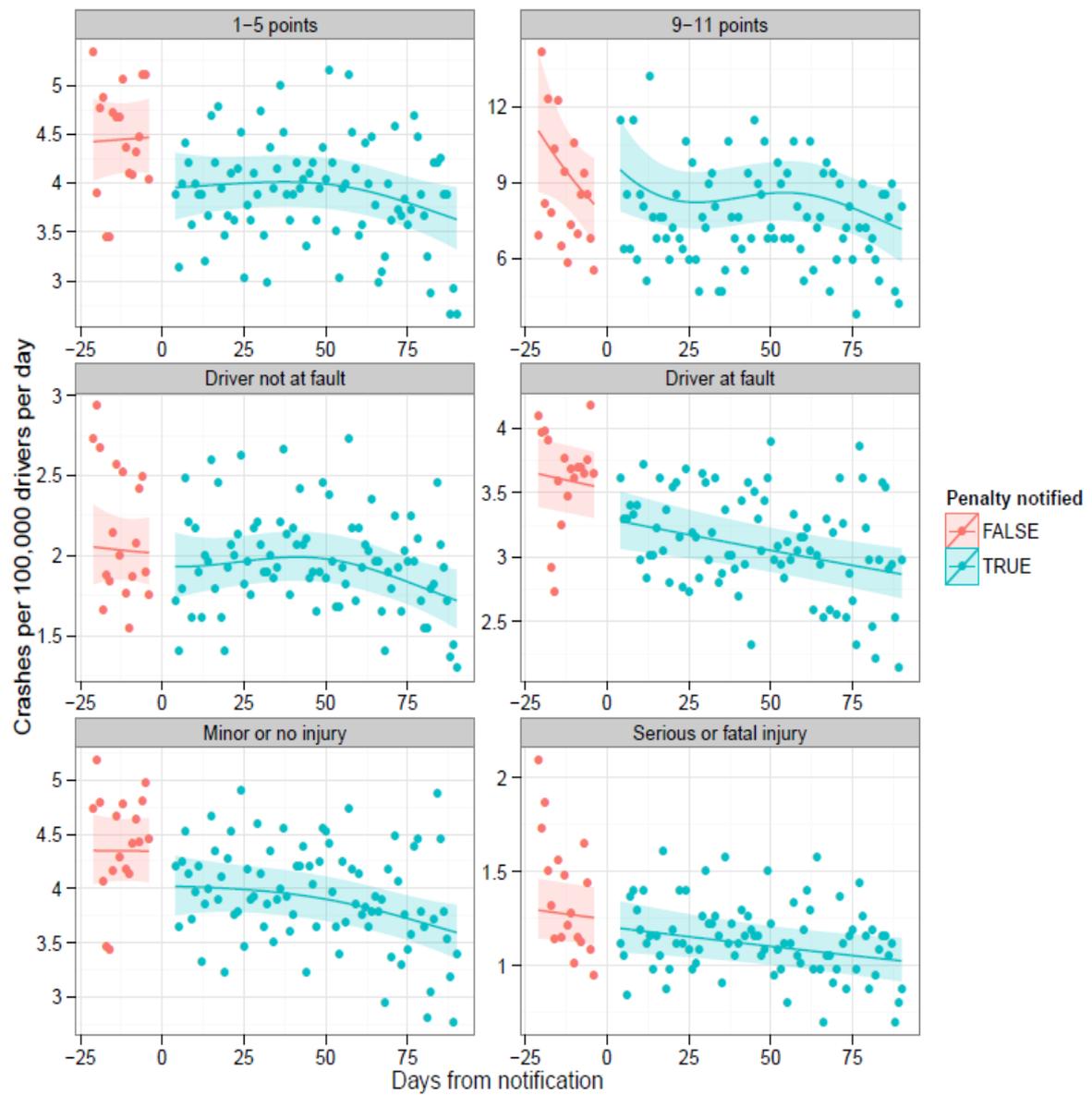


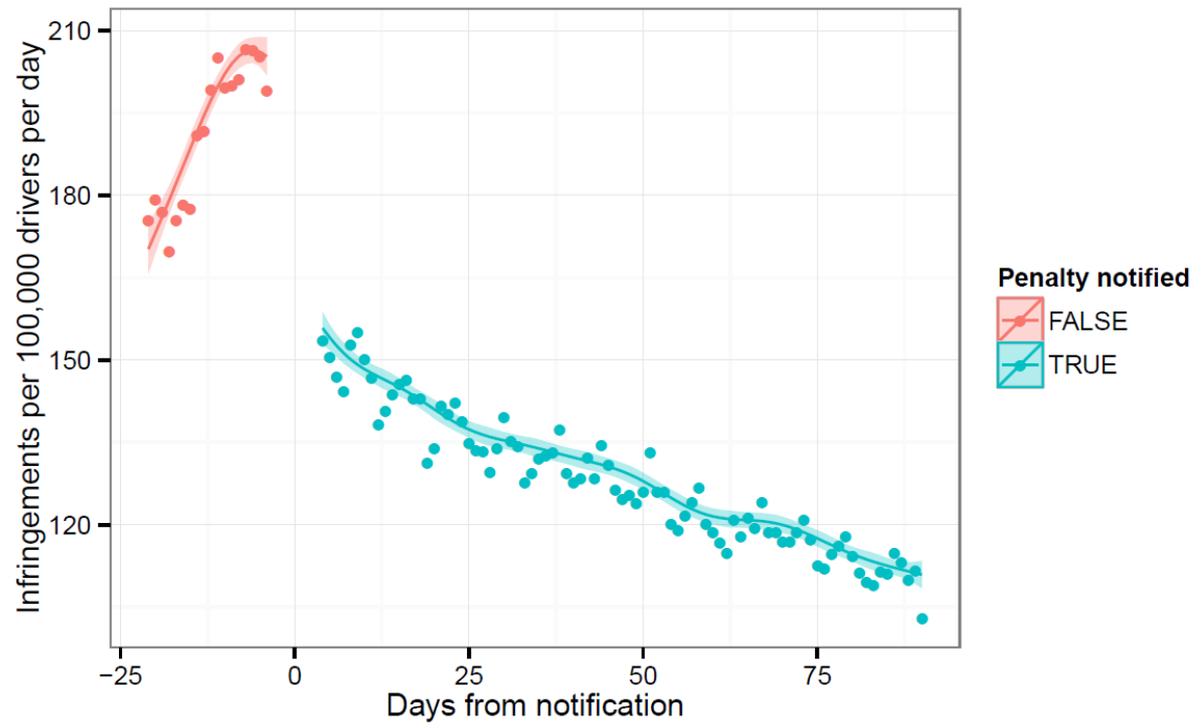
Figure 4. Discontinuity in the recidivism rate

Table 5. Multivariate predictors of recidivism *

	Rate ratio (95% CI)	P value
Notification	0.75 (0.73-0.78)	<0.001
Driver male (ref: Female)	1.31 (1.3-1.32)	<0.001
Driver age (ref: 20-25 years)		
26-30 years	0.87 (0.87-0.88)	<0.001
31-60 years	0.68 (0.67-0.68)	<0.001
>60 years	0.41 (0.41-0.42)	<0.001
Cumulative demerit points (ref: <5)		
5-8 points	1.35 (1.34-1.36)	<0.001
9-11 points	1.58 (1.56-1.6)	<0.001
>11 points	2.26 (2.23-2.28)	<0.001
Type of offense (ref: Red light violation)		
Speeding - minor	1.16 (1.15-1.17)	<0.001
Speeding - moderate	1.08 (1.06-1.09)	<0.001
Speeding - major	1.12 (1.11-1.14)	<0.001

* The model also included a smooth term to adjust for re-offending risk over time, and dummy variables indicating the number of days from notification modulo 7 to adjust for a day-of-week effect.

Figure 5. Discontinuities in recidivism rates within defined subgroups

