

1 *Penalties for Speeding and their Effect on*
2 *Moving Violations: Evidence from Quebec*
3 *Drivers*

4 Vincent Chandler
5 *Université du Québec en Outaouais*

6 Lealand Morin
7 *University of Central Florida*

8 Jeffrey Penney
9 *University of Alberta*
10

11 *Abstract.*

12 In 2008, the province of Quebec drastically increased penalties for speeding
13 well above the speed limit by doubling fines and instituting on-the-spot license
14 suspension. Using administrative driving and licensing records in Quebec from 2006
15 to 2010, we examine whether the new law discouraged unlawful driving behaviour
16 by investigating the frequency with which motorists received traffic citations. We
17 find that males became less likely to get traffic tickets after the law came into effect,
18 with the largest effects on those aged 16 to 24. However, females did not largely
19 change their behaviour in response to this new law.

20 Keywords: driving behaviour, law enforcement, risk aversion, speeding.

21 *Résumé.*

22
23 JEL classification: K42, K49

24 **1. Introduction**

25 In 2018, 1,743 individuals died in Canada following a car accident (Transport
26 Canada, 2018). Such accidents are the leading cause of death for individuals
27 aged between 15 and 44 (Statistics Canada, 2020). Many OECD countries
28 have recently introduced harsher punishments to deter the types of behaviour
29 that increase the likelihood of such tragedies. For example, penalties for

The authors would like to thank François Tardif for his help with the data in the early stages of this project. The usual caveat applies.

Canadian Journal of Economics / *Revue canadienne d'économique* 20XX 00(0)
January 20XX. Printed in Canada / *Janvier 20XX. Imprimé au Canada*

ISSN: 0000-0000 / 20XX / pp. 1-?? / © Canadian Economics Association

CAJE / Article ref: 00000 / Dispatch date: 01.01.20XX / No. of pages: 00

speeding well above the speed limit now typically include some combination of substantially increased fines, immediate vehicle seizure, and license suspension. These laws are typically referred to as excessive speeding laws or stunt-driving laws.

Quebec followed this trend and introduced excessive speeding penalties in 2008. Its provisions are triggered when driving well above the speed limit. For example, driving at a speed of 100km/h in a 60km/h zone would be considered excessive speeding. These harsher punishments received widespread media coverage both before and after its implementation, and there was a sustained campaign by the provincial government to help ensure drivers were aware of the law. The Quebec government has since declared the legislation to be successful, with the number of excessive speeding tickets decreasing over time. Furthermore, the number of accidents with bodily harm decreased from 36,816 in 2006 to 32,371 in 2010, and the number of accidents with fatalities decreased from 666 to 441 over the same period (Gendreau, M. and Pichette, F. and Tardiff, F. (2011)). Even though these findings are encouraging, they don't provide conclusive evidence that the harsher penalties truly caused changes in behaviour. The legislation has been unsuccessfully challenged in court.

Since Becker (1968), economists have theorized that harsher punishments alter the incentives of individuals and thus ultimately their behaviour. Helland and Tabarrok (2007) provide evidence for this mechanism studying the impact of California's three-strike legislation on the recidivism rates of felons. However, the effectiveness of deterrence is unclear in the context of driving. Indeed, Bourgeon and Picard (2007) hypothesize that some drivers may be impossible to deter either because they do not care about the penalties or because they are not aware they are speeding.

A broad literature has investigated the role of deterrence on driving and particularly alcohol consumption (e.g. Hansen (2015)), but less attention has been devoted to speeding. Some empirical research has determined the impact of very influential policies like the introduction of a demerit point system. For example, Benedittini and Nicita (2009) show a reduction in road fatalities through deterrence and incapacitation following the introduction of such a system. More generally, Castillo-Manzano and Castro-Nuño (2012) provide a meta-study demonstrating the broad positive impact of such a policy in a variety of countries. In Quebec, Dionne et al. (2011) focus on the threat of the loss of license on the behaviour of a driver close to the demerit point threshold of suspension. They find a reduction in the probability of violation for drivers with a large number of demerit points and conclude the system is successful in deterring the worst offenders. Finally, closest to this paper, Meirambayeva et al. (2014) show the introduction of a street-racing law in Ontario decreased the number of accidents using ARIMA modelling of the monthly number of accidents in Ontario.

In this paper, we investigate the effect of Quebec's excessive speeding legislation on the frequency and types of violations incurred by Quebec drivers

using an event-study design. Such violations are a proxy for driving behaviour, so this study will glean insight into the effect of increasing penalties on dangerous driving. It is important to note that we are looking at all violations which result in demerit points, and not just those that are affected by the change in the law.

We begin with a simple theoretical model to examine the predictions of economic theory on the effect of the law on drivers. The model predicts the possibility of heterogeneous effects by age and gender. We then use driving records obtained from administrative data sets of the Government of Quebec comprising the universe of violations from 2006 to 2010 and records on drivers' licenses over the same period. The use of large administrative datasets is necessary because only a small fraction of all drivers are impacted by the policy change; yet, these drivers are particularly important because they are generally responsible for accidents causing bodily harm and property damage. We examine the heterogeneous effects of the excessive speeding law on both the extensive margin (getting a ticket) and the intensive margin (getting a more severe ticket) across gender and age.

We find that the daily probability of receiving a ticket (extensive margin) decreases after the implementation of the law. When we examine the results by age group, we find that the effects vary substantially, with young drivers between the ages of 16 and 24 being the most affected by the law, while there is little effect for drivers over the age of 45. Repeating the analysis by gender, we see that both males and females change their behaviour, but the magnitude of the effect on males is about eight times that of females. Examining the breakdown by age categories, we see that the effect gradually declines for males until age 55, while there appears to be no age effect for females.

We then investigate the effect on the intensive margin. For males, the probability of getting tickets worth only one demerit point actually increases following the new policy, while tickets for all other point values decrease. This result suggests that male drivers are still exceeding the speed limit but are driving more slowly than before the introduction of the legislation. A similar pattern exists for female drivers for one and two point violations. We conclude that Quebec's 2008 excessive speeding law has had substantial spillover effects on both the extensive and intensive margins of driving behaviour. In other words, not only has it reduced the number of drivers driving well above the speed limit, it has also led to a decrease in the propensity to commit other moving violations.

This paper contributes to the literature in several ways. It is the first examination using administrative data into the effect of an excessive speeding law on driving behaviour as proxied by violations by gender and age group. Such analysis is important because most countries currently use demerit point systems. The question now is not whether these systems work but whether and how they can be adjusted to increase road safety. Moreover, this paper is to our knowledge the first one to empirically investigate the impact of such

laws on both the intensive and extensive margins of speeding. Finally, by studying the impact of deterrence by gender and age, this paper fills a gap acknowledged by Freeman (1999) on the role of gender in studies surrounding criminality.

The rest of this article is organized as follows. Section 2 covers the details of Quebec's excessive speeding law and the relevant institutional background. A simple theoretical model investigating the effects of the law is constructed in Section 3. The data and summary statistics are presented in Section 4. In Section 5, we conduct the empirical analysis. A series of robustness and placebo checks is conducted in Section 6. We conclude with a policy discussion in Section 7.

2. Institutional background

Vehicular conveyance in the province of Quebec is primarily overseen by a public organization known as the Société de l'assurance automobile du Québec, commonly abbreviated as SAAQ. This organization was legislated into existence in 1978 and has several mandates. First, it has a public monopoly on the portion of insurance that covers bodily injury. Second, it is responsible for enforcing two key pieces of legislation relating to driving: the Highway Safety Code and the Automobile Insurance Act.¹ Finally, it manages the driving records of Quebec drivers, including the demerit point system, and the organization promotes road safety through awareness campaigns.

The demerit point system generally operates along the following lines. If a driver is caught committing a violation, the police officer gives the person a ticket according to the violation in question. All violations include a fine and a number of demerit points. Drivers can either admit guilt by paying the ticket or challenge the sanction in court. The violation is recorded in the driver's file when the guilty plea is received or when the judge convicts the driver. The points are added to the driver's file when the violation is recorded and remain there for a period of 24 months. If drivers accumulate more than 20 points, they lose their license for at least 3 months after which time they can reapply for one.² They will only receive a new license if they successfully complete the theoretical and practical driving examinations.

Quebec's excessive speeding law came into force on April 1, 2008 and changed the demerit point system managed by the SAAQ.³ This change was advertised by the SAAQ both before and after the law came into effect.

1 A current list of offences that result in demerit points under the Highway Safety Code can be found at the following web address: <https://saaq.gouv.qc.ca/en/drivers-licences/demerit-points/offences-and-demerit-points/> (Accessed May 29, 2020).

2 This period of time increases every time drivers lose their licence.

3 On September 30, 2007, the Ontario government introduced legislation against street racing. If drivers decided to go to Québec to engage in street racing to avoid this law,

	First offence	Second offence	Third offence	Subsequent offences
License suspension	7 days	30 days	60 days if all three offences were committed in a zone under 60km/h zone, otherwise 30 days	60 days if this offence and at least two others were committed in a zone under 60km/h zone, otherwise 30 days
Vehicle seizure	none	30 days if both offences committed in a zone of 60km/h or less	30 days if this offence and at least one other were committed in a zone of 60km/h or less	30 days if this offence and at least one other were committed in a zone of 60km/h or less
Fines	doubled	doubled	doubled	doubled
Demerit Points	doubled	doubled	doubled	tripled

TABLE 1
Penalties for Excessive Speeding

Excessive speeding is defined by the law as exceeding the speed limit by 40 km/h in a zone of 60 km/h or less, by 50 km/h in a zone between 60 to 90 km/h, and by 60 km/h in a zone where the speed limit is equal to or greater than 100 km/h. The law worked in tandem with the then currently legislated speeding violations, increasing fines and demerit point penalties and imposing license suspensions and vehicle seizures. Although offences involving demerit points remain on a person's driving record for two years, excessive speeding convictions remain on a person's driving record for 10 years. Table 1 details the penalties for violating the excessive speeding law. Note that the license suspension and vehicle seizure occur immediately after being pulled over regardless of the driver's innocence or guilt, while the fines and demerit points are only entered into the record once the individual admits guilt or is later found guilty in a court of law.

these tickets would not be in this database, because these drivers would not have a Quebec drivers license.

3. Theoretical Model

In this section, we present a simple theoretical model of driving behaviour. We use this to appeal to economic theory to determine whether to expect differences in age and gender as a result of a policy that increases the risk of driving, and if so, whether there would be a pattern in these differences. We later use the conclusions reached from this analysis as predictions of the results of the empirical model.

Consider the utility maximization problem for the representative agent

$$u_j(s) = g(s) - r_j(s)$$

where $g(s)$ is the utility of driving at speed s and $r_j(s)$ is the disutility from the risk of driving at speed s , and j indexes males and females $\{m, f\}$; therefore, we assume the representative male and the representative female have different risk preferences (and therefore utility functions). Assume $g(s)$ is concave increasing ($g'(s) > 0, g''(s) < 0$) and $r_j(s)$ is convex increasing ($r'_j(s) > 0, r''_j(s) > 0$). Let $g(s)$ and $r_j(s)$ be continuous in the positive orthant. Impose the regularity conditions $g(s) \geq 0 \forall s$ and $r_j(s) \geq 0 \forall s$. Let there exist values of s such that $g(s) > r_j(s) > 0$; this guarantees the existence of a non-trivial equilibrium. Taking the first order condition of the objective function, the ideal speed s^* is chosen such that $g'(s) = r'_j(s)$, and this is a global maximum because $u''_j(s) = g''(s) - r''_j(s) < 0$. Plotting each curve separately on a graph, the maximum point s^* is the one such that the vertical distance between the concave and convex curves is maximized, and this occurs at the point where the slopes are equal. Let $r_m(s) < r_f(s) \forall s$; that is, the perceived risk of driving at any given speed is higher for females than it is for males (Croson and Gneezy, 2009). Graphically, the risk function for the representative females will be more convex than it is for the representative male. Examining the first order conditions, we see that, on average, males will drive faster than females ($s_m^* > s_f^*$) since $u'_m(s) = g'(s) - r'_m(s) > g'(s) - r'_f(s) = u'_f(s)$.

Proposition 1. *Suppose the risk profile increases for both males and females such that driving at speed s produces a risk of $r_j(s + \epsilon)$. Then, the decrease in driving speed for males will be greater than the decrease in driving speed for females.*

Proof: Let the new equilibrium point be labelled s_j^{**} . It is immediate that $s_j^* > s_j^{**}$ for both $j = \{m, f\}$ by the convexity of $r_j(s)$. By the concavity of $g(s)$ and because $r_m(s) < r_f(s) \forall s, (s_m^* - s_m^{**}) - (s_f^* - s_f^{**}) > 0$.

Informally, the female objective function for the representative female will reach its new equilibrium speed sooner because both $g(s)$ and $r_j(s)$ are steeper when moving from the old equilibrium to the new equilibrium.

207 This theoretical model predicts that people who are more risk averse
 208 towards a certain behaviour are less likely to be affected by additional
 209 disincentives for that behaviour. If the penalties for speeding increase, females
 210 are less likely to be affected because they are more risk averse. The model can
 211 analogously be applied to age: younger people tend to be more risk seeking
 212 (e.g. Gong and Yang (2012)), so we also predict that our empirical results
 213 will show that the effect of the law on risk taking behaviour in driving will
 214 decrease with age.

215 4. Data

216 We use records of traffic violations and drivers licenses obtained from SAAQ
 217 administrative data to generate a dataset containing the universe of driver-
 218 days from April 1, 2006 to March 31, 2010 for the province of Quebec.⁴ Our
 219 dataset contains information on the age, gender, and details concerning traffic
 220 violations of the offender. In all, we have approximately 9.7 billion driver-day
 221 observations over the sample period. This very large sample will afford us the
 222 opportunity to examine detailed subgroups and give us the statistical power
 223 to detect effects that are small in absolute magnitude.

224 We begin with a graphical analysis of some select demerit point values.
 225 Here, we examine monthly ticket frequencies for given point values before and
 226 after the policy change. Unfortunately, the dataset makes it impossible to
 227 distinguish between single and multiple violations for a single police stop. For
 228 example, it is impossible to distinguish a driver with two 3-point violations
 229 from a driver with a single 6-point violation—all we observe is that both
 230 drivers gained 6 demerit points on a given day. Fortunately, multiple violation
 231 stops are likely very rare in our sample.⁵

232 Since the demerit point values of some violations have doubled after the
 233 excessive speeding law came into effect under certain conditions (see Section
 234 2 for details), we will compare stops associated with a certain number of
 235 points before the policy change with those associated with the same number of
 236 points and double the number of points after the policy change. For example,
 237 a driver speeding 46km/h to 49km/h over the speed limit before the policy
 238 change would receive a 5-point ticket, but the same violation would be worth
 239 10 points after the policy change if it qualifies for excessive speeding. Because

4 The dataset on driver's licenses allows us to include observations that do not receive any tickets during the sample period.

5 For example, before the excessive speeding law, there were no violations worth 6 points, but the sample shows 517 stops resulting in 6 demerit points compared to 43,006 stops resulting in 5 demerit points. As another example, a single 7-point violation was present before the policy change, but none after; the number of 7-point tickets before the policy change was 8,366, and it decreased to only 24 after the policy change. There are no violations in the Highway Safety Code worth 8 or 11 demerit points at any time in our sample period, and our data shows no stops with demerit point totals of these values.

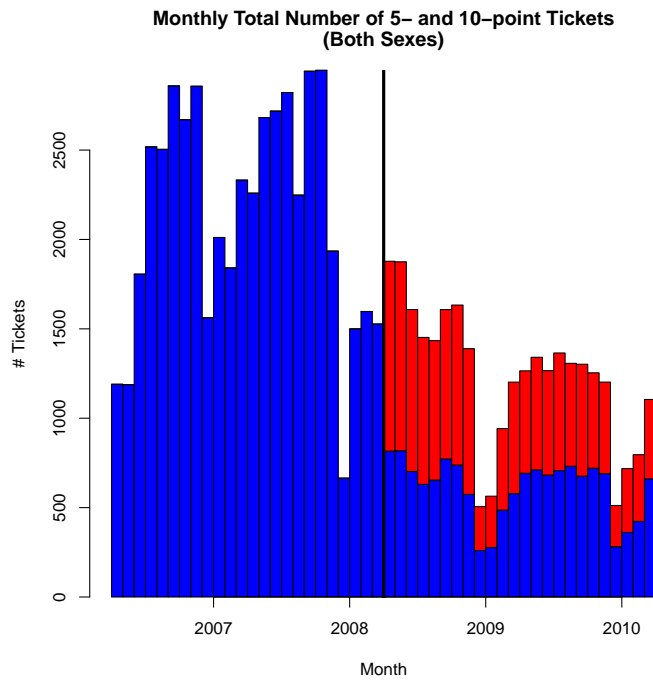


FIGURE 1 Monthly frequency of 5- and 10-point violations

Notes: Authors calculations. Monthly frequency of 5-point violations before the policy change and 5- or 10-point violations after the policy change. Blue areas correspond to 5 point-stops, while red areas are 10-point stops.

excessive speeding doubles the point values of some speeding violations, we will need to compare the frequency of 5-point stops before the policy change to 5- or 10-point stops afterwards (as not all 5-point speeding violations may qualify as excessive speeding). Due to the aforementioned possibility of stops with multiple violations, the number of tickets with 5- or 10-point values will contain combinations of violations which will be counted in the post period that were not counted in the pre period, and so the effect of the law will be underestimated in this case, but the overall effect should be minimal.

If drivers do not adjust their behaviour, there should be about as many drivers with 5 points before the policy as there were drivers with 5 or 10 points after the policy. If drivers slow down, the number of 5-point or 10-point violations will decrease.

Taking into consideration the seasonality of speeding, we see in Figure 1 an important reduction in the number of 5- or 10-point tickets in the

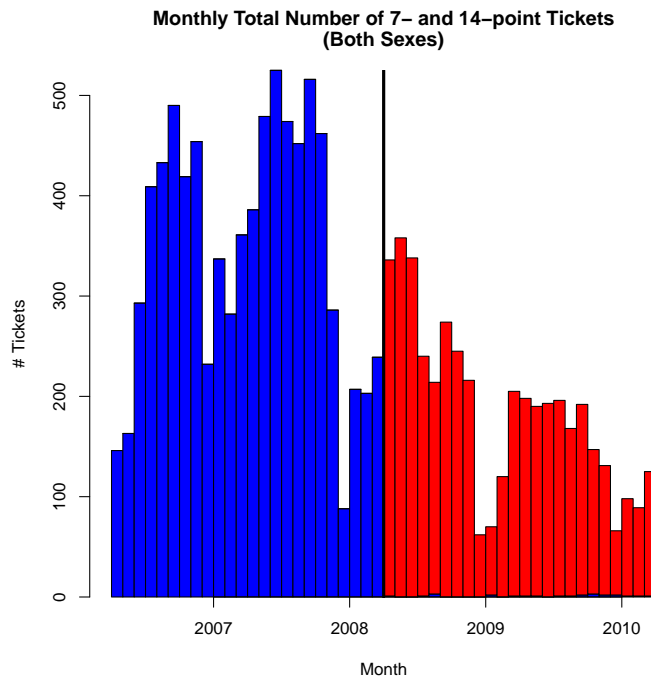


FIGURE 2 Monthly frequency of 5- and 10-point violations

Notes: Authors calculations. Monthly frequency of 7-point violations before the policy change and 7- or 14-point violations after the policy change. Blue areas correspond to 7-point stops, while red areas are 14-point stops.

254 summer of 2008, compared to the preceding summer. Overall, there is a general
 255 downward trend in the number of tickets after the policy change compared to
 256 before the policy change, and the 5- and 10-point tickets after the change are
 257 approximately evenly split.

258 With 7- or 14-point stops, in Figure 2, we see a different picture: nearly all
 259 7-point violations are worth 14 points after the policy change, while only a
 260 few 7-point violations remain. Since there is no violation worth 7 points after
 261 the policy change, all of the 7-point stops after the policy change are due to
 262 being pulled over for multiple violations totalling 7 points. Once again, we see
 263 a downward trend in the number of total violations.

264 Table 2 reports summary statistics. Overall, since females represent half of
 265 drivers yet only 20% of traffic violations, they represent a far smaller share of
 266 those who receive tickets compared to males. In the 1- and 2-point categories,
 267 the number of tickets increases for both males and females on a per driver-

Points	Male Drivers		Female Drivers		Gender Ratio (Percent Males)	
	Pre	Post	Pre	Post	Pre	Post
1	101,298	122,899	45,382	61,778	69	67
2	533,167	572,194	249,669	283,108	68	67
3	701,053	627,807	247,991	239,554	74	72
4	15,567	15,278	2,216	2,470	88	86
5	43,006	12,368	8,172	2,272	84	84
6	496	12,000	21	3,296	96	78
7	7,688	18	648	6	92	75
9	7,382	5,791	2,587	2,431	74	70
10	0	12,747	0	2,137		86
12	127	0	1	0	99	
14	0	4,145	0	302		93
15	17	0	1	0	94	
18	3	560	0	23	100	96
24	0	98	0	4		96
30	0	17	0	0		100
36	0	4	0	0		100
Total	1,409,804	1,385,926	556,688	597,381	72	70

TABLE 2

Frequency of tickets by point value

The headings “Pre” and “Post” columns refer to offences that occurred before and after the policy change. The gender ratio is measured as the percentage of the number of offences committed by males divided by the total number of offences committed by all drivers.

day basis, and generally decreases in the higher-point categories, even though more violations lead to an increase of points.

To put these numbers in a broader context, the vast majority of the sample are non-events. Before the excessive speeding law came into effect, the average driver has a probability of 0.04% to receive a ticket on any particular day. This probability decreases by approximately 3.6% after the policy change. If we look at the demerit points per driver per day, they decreased after the policy change for males by 6% and by 1% for females. This result is particularly interesting, because excessive speeding penalties doubled the value of many speeding violations previously worth 5, 7, and 9 points.⁶ In the absence of a change in behaviour, the number of demerit points per driver per day would have mechanically increased.

⁶ Some 3-point speeding tickets are subject to the excessive speeding law, but the circumstances are quite particular: the suspect needs to be exceeding the speed limit in a zone with a posted limit of 60km/h or less by 40 to 45 km/h.

5. Empirical Analysis

5.1. Regression results for any moving violation

We analyze the effect of the excessive speeding law on traffic tickets by means of an event study. The main regression specification is

$$y_{it} = \beta_0 + \beta_1 d_t + \beta_2 d_t \mathbf{agecat}_{it} + \beta_3 \mathbf{agecat}_{it} + \beta_4 \mathbf{ptsgrp}_{it} + \beta_5 \mathbf{calendar}_{it} + \varepsilon_{it}$$

where d_t is a dummy variable equal to 1 after the policy change and 0 before, **agecat** is a set of age category dummies, **ptsgrp** is a set of demerit point balance categories, **calendar** is a set of month and weekday indicator variables, and ε_{it} is the usual error term.⁷ The dependent variable y_{it} is equal to 1 if individual i received a ticket on day t and 0 otherwise. The age category controls are 16 to 19, 20 to 24, 25 to 34, 35 to 44, 45 to 54, 55 to 64, and 65 and over. The demerit point balance is the sum of demerit points on a driver's record over the last two years. This variable is divided in to categories of 1 to 3, 4 to 6, 7 to 9, and 10 and over.

For the regressions in this study, we estimate both the linear probability model and the logistic model. Where there is statistical significance at our elevated thresholds (see below), the estimates are nearly always quantitatively similar. For expositional simplicity, we will focus our interpretation on the marginal effects of the linear probability model.

Our coefficients of interest are the scalar β_1 and the vector β_2 . We include the vector β_2 in some specifications and run some regressions separating by gender because the theoretical model of Section 3 predicted the possibility of heterogeneous effects due to differential attitudes towards risk: females and those of higher ages are likely to be more risk averse.

We begin by running the regression using the full sample. Due to the very large sample sizes being employed, we elect to consider only statistical significance at the 0.1% and the 0.001% level. In the full sample, we see that the imposition of the policy increases the daily probability of receiving a ticket by 0.00382 percentage points, and this is very precisely estimated (t -statistic = -92.992). Once we add the age and policy interactions, the coefficient on the policy dummy is no longer significant, and we see very heterogeneous effects by age group. Most of the effect is concentrated in the 16 to 19 and 20 to 24 age groups, and then the magnitude declines steadily afterwards. The effect loses statistical significance at the 0.1% level once we reach the 45 to 54 age group.

The theoretical model of Section 3 suggests that the effects differ by gender. We thus rerun the model, separating the sample by gender, the results of which are displayed in Table 3.⁸ In the sample using only males, we see that the effect

⁷ Note that the bolded items represent vectors rather than scalars.

⁸ For readability, we multiply the estimated coefficients and standard errors by 100,000 for all tables of regression results for the linear probability model.

	Logistic Regression				Linear Probability Model		
	Marginal Effect	Estimate	Standard Error	Sig.	Estimate	Standard Error	Sig.
Male Drivers (5,335,033,221 observations)							
Model without age-policy interaction:							
Policy	-5.8437	-0.1113	0.0012	**	-5.9663	0.0628	**
Model with age-policy interaction:							
Policy	-0.3718	-0.0195	0.0386		-1.0915	0.7342	
Age 16-19 * policy	-11.9953	-0.1107	0.0389		-11.1587	0.9191	**
Age 20-24 * policy	-12.5311	-0.1300	0.0387	*	-11.9225	0.8017	**
Age 25-34 * policy	-8.7645	-0.1301	0.0387	*	-8.6158	0.7536	**
Age 35-44 * policy	-4.9762	-0.0891	0.0387		-5.0295	0.7484	**
Age 45-54 * policy	-3.3723	-0.0713	0.0387		-3.5740	0.7450	**
Age 55-64 * policy	-2.2322	-0.0594	0.0387		-2.5200	0.7455	*
Age 65+ * policy	0.0272	0.0011	0.0389		-0.2808	0.7427	
Female Drivers (4,340,212,273 observations)							
Model without age-policy interaction:							
Policy	-0.7814	-0.0294	0.0019	**	-0.8000	0.0495	**
Model with age-policy interaction:							
Policy	-0.3698	-0.0760	0.1304		-0.7470	0.6348	
Age 16-19 * policy	2.5302	0.0625	0.1307		0.7804	0.7413	
Age 20-24 * policy	1.7501	0.0415	0.1305		-0.0442	0.6765	
Age 25-34 * policy	0.6855	0.0200	0.1304		-0.9585	0.6483	
Age 35-44 * policy	1.6106	0.0508	0.1304		0.0531	0.6458	
Age 45-54 * policy	1.0893	0.0450	0.1304		-0.1831	0.6424	
Age 55-64 * policy	1.0258	0.0587	0.1305		0.1339	0.6424	
Age 65+ * policy	1.4736	0.1335	0.1306		0.9727	0.6416	

TABLE 3

Regressions for all offences

For each regression, the dependent variable is an indicator that a driver has committed any offence on a particular day. All regressions contain age category and demerit point category controls, as well as monthly and weekday indicator variables. The baseline age category comprises drivers under the age of 16. The heading “Sig.” is an abbreviation for statistical significance, with the symbol * denoting statistical significance at the 0.1% level and ** the 0.001% level. In the linear probability model, coefficients and heteroskedasticity-robust standard errors are multiplied by 100,000.

315 increases the daily probability of receiving a ticket by 0.00597 percentage
316 points, an effect that is approximately 55% higher than in the pooled sample.
317 Once we add the policy and age group interactions, the coefficient on the policy
318 dummy again becomes insignificant, and the effect appears to be driven by
319 the age groups. Examining the coefficients, we see a very distinct pattern: the

effect is similar between the ages of 16 and 24, and the effect begins to decline throughout the entire lifecycle, although the effect is no longer significant at the 0.1% level for the age 65 and over age group.⁹

Conducting the regression for the females in the sample shows that the effect is much smaller for this group: the effect size of the coefficient on the policy dummy is 13.4% of the size of its counterpart in the regression for males. Once the age interactions are added, none of the coefficients are significant at the elevated 1% level. These findings suggest that the pooled results are driven almost entirely by males under the age of 65.

It is important to note that the estimate of the effect of the law in the main regression can be interpreted as an average treatment effect; this treatment effect includes drivers who rarely sufficiently exceed the speed limit or otherwise break the law to be penalized with traffic tickets. Assuming these more careful drivers are not affected by the law at all and that they make up a large segment of the population, the effect of the law on the relevant subpopulation that is affected by the law may be well underestimated.¹⁰

5.2. Regression results by point total

In this section, we examine the effects of Quebec's excessive speeding law by point total. We repeat the policy dummy specification in Section 5.1 but run a regression for each particular ticket point value: 1, 2, 3, 4, 5, 7, and 9 or more points. For each of these regressions, the dependent variable is equal to 1 if the driver earns a ticket of that point value on that day, and is equal to 0 otherwise. This strategy will allow us to investigate the changes in the intensive margin of demerit points given to drivers after the policy change. Individuals may substitute driving well above the speed limit with driving at lower speeds but still above the speed limit. As before, the demerit points lost after the policy change take into account the doubling of the penalty due to the excessive speeding law. For example, the 5-point category therefore includes tickets worth 5 points before the policy change and 5 or 10 points after the policy change. These effects might be slightly underestimated (that is, they

9 While the marginal effects of the logistic model for the age-policy interaction variables in Table 3 closely follow those of the linear probability model, they are less precisely estimated. One reason this could be the case is that the coefficients and standard errors for interaction terms in logistic models cannot be correctly derived theoretically, and must instead be found analytically (Ai and Norton, 2003); the linear probability model does not have this limitation.

10 Whether to interpret these estimates as average treatment effects is a question that has not yet been broached in the literature. We briefly consider this issue here. Since the entire population is being treated by the policy change, one can argue that the average treatment effect (ATE) equals the average treatment effect on the treated (ATT). However, one may claim that since the law was only meant to catch people who routinely speed in the first place, this subpopulation of habitual speeders make up the treatment group and thus the average effect on them would be the ATT, while the ATE refers to the average effect on the whole population.

	Logistic Regression				Linear Probability Model		
	Marginal Effect	Estimate	Standard Error	Sig.	Estimate	Standard Error	Sig.
Male Drivers (5,335,033,221 observations)							
All point values	-5.8437	-0.1113	0.0012	**	-5.9663	0.0628	**
1 point	0.3996	0.0953	0.0043	**	0.3930	0.0177	**
2 points	-0.3961	-0.0191	0.0019	**	-0.4315	0.0394	**
3 points	-4.7237	-0.1872	0.0017	**	-4.7786	0.0436	**
4 points	-0.0726	-0.1252	0.0114	**	-0.0804	0.0066	**
5 points	-0.8405	-0.6470	0.0080	**	-0.8189	0.0100	**
7 points	-0.1679	-0.7392	0.0193	**	-0.1625	0.0042	**
9 or more points	-0.0660	-0.2501	0.0170	**	-0.0675	0.0045	**
Female Drivers (4,340,212,273 observations)							
All point values	-0.7814	-0.0294	0.0019	**	-0.8000	0.0495	**
1 point	0.5217	0.2124	0.0062	**	0.5174	0.0150	**
2 points	0.3713	0.0303	0.0028	**	0.3613	0.0336	**
3 points	-1.4247	-0.1256	0.0029	**	-1.4289	0.0323	**
4 points	-0.0011	-0.0098	0.0293		-0.0010	0.0032	
5 points	-0.2225	-0.7494	0.0187	**	-0.2105	0.0053	**
7 points	-0.0208	-0.9113	0.0695	**	-0.0191	0.0015	**
9 or more points	-0.0180	-0.1541	0.0282	**	-0.0180	0.0033	**

TABLE 4

Regressions by ticket-point value

In each row, the dependent variable is an indicator that a driver has committed an offence with the stated point value on a particular day. The categories of tickets with 3, 5 and 7 points includes tickets with 6, 10 and 14 points after the policy change, respectively, and the category with 9 or more points includes tickets with all corresponding doubled values after the policy change. All regressions contain age category and demerit point category controls, as well as monthly and weekday indicator variables. The baseline age category comprises drivers under the age of 16. The heading "Sig." is an abbreviation for statistical significance, with the symbol * denoting statistical significance at the 0.1% level and ** the 0.001% level. In the linear probability model, coefficients and heteroskedasticity-robust standard errors are multiplied by 100,000.

may have a slight downward bias) since some ticket combinations yielding 10 points after the policy change would be captured by these regressions. However, as previously argued, these sorts of incidents are likely very rare.

We see the results of these regressions by ticket point in Table 4. For males, we see a very minor increase in the number of tickets worth 1 point after the policy change. This increase in 1-point tickets is dwarfed by the decrease in the tickets in all of the other point categories and is alone cancelled out by the decrease in two point tickets. For females, a similar pattern is found in that 1- and 2-point tickets increase slightly, but this increase is more than cancelled out by the decrease in 3-point tickets. There is a decrease in 4-point tickets, but it is not precisely estimated. All ticket values of 5 or more points decrease

after the policy change. Note that the coefficient sizes for some of the higher ticket point categories on Table 4 are quite small: this is because high ticket values are rare, and so any decrease in them will have a smaller coefficient, since it represents a change from one small number to another small number. These patterns suggest that many drivers have decreased their maximum speed after the policy change. It appears likely that many people who used to speed well above the limit have decreased their speed such that they are still exceeding the limit, but not as much as before. Since the extensive margin of tickets has decreased, it looks like many who used to speed at moderate speeds over the limit are now no longer speeding.

5.3. Regression results for drivers with high point balances

It may be of interest to know how drivers who typically drive less carefully (and thus accumulate more demerit points) may have seen their point balances shift on average after the implementation of the policy. We examine the subsample of drivers who at one point in the pre-period had a point balance of between 6 and 10 demerit points using the regression specification of Section 5.1. Therefore, two categories of drivers are excluded: those whose point balance never reaches 6 (most of the sample), and those who received serious tickets and therefore whose point balance is never in this range. For example, a person who received a singular ticket for excessive speeding worth 12 demerit points will not be a part of this sample because their point balance will remain at 12 as long as the ticket is on their record, and the balance will drop down to 0 when the ticket's demerit points expire: at no point was this driver's demerit point balance between 6 and 10. We need to exclude these drivers to avoid issues associated with the drivers' licence revocation. Indeed, a revocation would necessarily lead to a reduction in the number of violations in the post-policy period, because the individual is not allowed to drive. The results of this exercise by gender are on Table 5 below.

For both males and females, the effect of the policy both in general and by ticket point value shows much larger effects in the negative direction. For example, the effect of the policy on males for 3-point tickets is five times larger in the high point group compared to the overall sample. Overall, the frequency of tickets decreases by a relatively large margin for this group of drivers after the policy.

6. Concerns of Validity

6.1. Alternative explanations for the downturn in tickets

To examine the possibility that these results are driven by secular trend, we repeat the regression specified in Section 5.1 by splitting the pre-period in half. Because of the very heterogeneous effects by gender, we perform two sets of placebo checks using the regression specification from Section 5.1, one

	Logistic Regression				Linear Probability Model		
	Marginal Effect	Estimate	Standard Error	Sig.	Estimate	Standard Error	Sig.
Male Drivers (921,131,812 observations)							
All point values	-38.7680	-0.3732	0.0021	**	-38.0770	0.2114	**
1 point	-0.5569	-0.0735	0.0076	**	-0.5454	0.0572	**
2 points	-7.7408	-0.2111	0.0035	**	-7.7125	0.1261	**
3 points	-25.0995	-0.4677	0.0029	**	-24.5075	0.1520	**
4 points	-0.9635	-0.8975	0.0228	**	-0.8445	0.0205	**
5 points	-3.6458	-1.0016	0.0124	**	-3.3206	0.0393	**
7 points	-0.8298	-1.1495	0.0291	**	-0.7270	0.0173	**
9 or more points	-0.3835	-0.7647	0.0319	**	-0.3543	0.0145	**
Female Drivers (249,294,614 observations)							
All point values	-26.6111	-0.4252	0.0052	**	-26.0411	0.3154	**
1 point	-0.1042	-0.0239	0.0193		-0.0916	0.0830	
2 points	-5.9578	-0.2441	0.0082	**	-5.9044	0.1970	**
3 points	-18.2815	-0.5749	0.0075	**	-17.6976	0.2250	**
4 points	-0.2894	-1.2986	0.1060	**	-0.2424	0.0181	**
5 points	-1.9115	-1.3612	0.0425	**	-1.6387	0.0469	**
7 points	-0.2556	-1.6962	0.1444	**	-0.2020	0.0151	**
9 or more points	-0.2922	-1.1624	0.0942	**	-0.2568	0.0202	**

TABLE 5

Regressions for high-point drivers by ticket-point value

In each row, the dependent variable is an indicator that a driver has committed an offence with the stated point value on a particular day. The categories of tickets with 3, 5 and 7 points includes tickets with 6, 10 and 14 points after the policy change, respectively, and the category with 9 or more points includes tickets with all corresponding doubled values after the policy change. All regressions contain age category and demerit point category controls, as well as monthly and weekday indicator variables. The baseline age category comprises drivers under the age of 16. The heading "Sig." is an abbreviation for statistical significance, with the symbol * denoting statistical significance at the 0.1% level and ** the 0.001% level. In the linear probability model, coefficients and heteroskedasticity-robust standard errors are multiplied by 100,000.

401 for males and one for females. The results of this analysis are displayed in
402 Table 6.

403 The regression results show no statistical evidence of pre-trends, and none
404 of the coefficients of interest are precisely estimated. Moreover, the magnitude
405 of the coefficients in both placebo regressions for the model without age-policy
406 interactions are very similar and are far smaller than their counterparts in
407 the real regressions; we argue that this is evidence of precisely estimated

	Logistic Regression				Linear Probability Model		
	Marginal Effect	Estimate	Standard Error	Sig.	Estimate	Standard Error	Sig.
Male Drivers (2,618,869,394 observations)							
Model without age-policy interaction:							
Policy	-0.1306	-0.0024	0.0017		-0.2109	0.0905	
Model with age-policy interaction:							
Policy	-1.0816	-0.0572	0.0540		-1.8092	1.0215	
Age 16-19 * policy	-1.1919	-0.0106	0.0545		-2.9360	1.3097	
Age 20-24 * policy	2.0452	0.0204	0.0542		-0.1000	1.1226	
Age 25-34 * policy	3.1979	0.0457	0.0542		1.3441	1.0507	
Age 35-44 * policy	2.8146	0.0496	0.0542		1.2368	1.0420	
Age 45-54 * policy	3.3188	0.0698	0.0542		1.9795	1.0375	
Age 55-64 * policy	3.3223	0.0879	0.0543		2.3344	1.0386	
Age 65+ * policy	3.0624	0.1316	0.0545		2.7337	1.0342	
Female Drivers (2,109,880,942 observations)							
Model without age-policy interaction:							
Policy	-0.1544	-0.0059	0.0027		-0.1803	0.0706	
Model with age-policy interaction:							
Policy	0.8436	0.1696	0.1874		0.6983	0.9249	
Age 16-19 * policy	-7.6621	-0.1940	0.1879		-1.1349	1.0789	
Age 20-24 * policy	-6.9768	-0.1686	0.1875		-0.0914	0.9821	
Age 25-34 * policy	-6.3051	-0.1848	0.1875		-1.0372	0.9438	
Age 35-44 * policy	-6.1347	-0.1970	0.1875		-1.4878	0.9396	
Age 45-54 * policy	-4.0237	-0.1681	0.1875		-0.8437	0.9355	
Age 55-64 * policy	-2.5844	-0.1496	0.1876		-0.6454	0.9358	
Age 65+ * policy	-1.0819	-0.1028	0.1878		-0.3173	0.9345	

TABLE 6

Placebo regressions for all offences

For each regression, the dependent variable is an indicator that a driver has committed any offence on a particular day. All regressions contain age category and demerit point category controls, as well as monthly and weekday indicator variables. The baseline age category comprises drivers under the age of 16. The heading "Sig." is an abbreviation for statistical significance, with the symbol * denoting statistical significance at the 0.1% level and ** the 0.001% level. In the linear probability model, coefficients and heteroskedasticity-robust standard errors are multiplied by 100,000.

408 zeros given their magnitude and small standard errors.¹¹ If there were a

11 Even with the very large sample employed in this analysis, unless the effect is exactly zero in the population, a non-zero standard error and coefficient estimate will be still be produced. For a discussion on precise zeros, see Penney (2013).

409 secular trend in the pre-period driving the results of the main regressions, the
 410 male coefficient would have a substantially larger magnitude than the female
 411 coefficient, but this is not the case. In the set of regressions containing the age
 412 category dummies interacted with the policy variable, none of the interactions
 413 are statistically significant, and there is no pattern among the coefficients
 414 either. This result contrasts with the coefficients on the age interactions for
 415 males in the main regression in which we observe a clear pattern: the effect
 416 is similar from ages 16 to 25, and then slowly declines with age. Overall, we
 417 do not find any convincing evidence that the effects found in the real main
 418 regression are an artifact of something other than the excessive speeding laws.

419 An alternative explanation is the idea that police leniency may have
 420 changed as a result of the law; we examine this possibility here. The
 421 introduction of additional penalties for excessive speeding may motivate police
 422 officers to note tickets as lesser speeding violations. For example, excessive
 423 speeding in zones with a limit of 60km/h could be marked down to a 3-
 424 point ticket, while excessive speeding in zones with higher limits could be
 425 reduced to a 5-point ticket. Three arguments speak against this possibility.
 426 First, police officers could behave in this fashion to avoid appearing in court
 427 in case the driver contests the charges. In Quebec, however, police officers are
 428 not required to appear in traffic court.¹² Second, a police officer aiming to
 429 be lenient would reduce the speed on a ticket to a level where the excessive
 430 speeding provisions would not take effect. However, according to Table 4, the
 431 incidence of tickets for men decreases for every category above 1 point, while
 432 for women it decreases for every category above 2 points. In other words, the
 433 categories to which the tickets would be marked down (3-point or 5-point
 434 tickets) still saw decreases.¹³ Finally, the overall number of tickets per driver-
 435 day still decreased (the extensive margin), and leniency against the provisions
 436 of the excessive speeding law would only affect the intensive margin of demerit
 437 points. We conclude it is very unlikely that a change in police leniency could
 438 be driving the results.

439 An increase in police vigilance during the implementation of the policy
 440 could also have affected the magnitude of the results. Indeed, it would have
 441 increased the number of tickets written in that period, which would result in
 442 an underestimation of the effect. Differences in police vigilance, should these
 443 have occurred, appear unlikely to have substantially increased the number of
 444 tickets overall, although these may have increased the number of excessive

12 See the following website (in French) for details:
<https://educaloi.qc.ca/capsules/la-contestation-dune-contravention/> (Accessed
 July 18, 2020).

13 Note that there are no speeding violations worth 4 points under the Quebec highway
 safety code, and that 4-point tickets are much less common than 3-point or 5-point
 tickets, see Table 2.

speeding tickets. We conclude that this should not be a significant concern in interpreting our results.

During about the last third of the sample period after the policy change, the province of Quebec introduced a photo radar pilot. It started issuing tickets for speeding on August 19, 2009. We do not believe this had a substantial effect on driver behaviour for several reasons. First, the number of photo radar machines was very small: there were 15 in the entire province of Quebec, which had a population of approximately 8 million people at the time.¹⁴ Second, during the pilot, the photo radar machines were placed in plain sight, and warning signs were placed ahead of them to clearly alert drivers of their location.

One last consideration is that, in January 2008, the Quebec government also introduced new legislation banning the use of handheld mobile devices while driving. This new violation associated with 5 demerit points could have increased the number of violations in the dataset. In 2008, there were 17, 986 violations for this charge and 44, 479 in 2009 (SAAQ, 2010, table 1.3). They represent 1.85 percent of all violations in 2008 and 4.64 percent in 2009. Despite the introduction of these new violations, we still observe a decrease in the total number of violations, suggesting our results could be underestimating the real impact of the excessive speeding laws.

6.2. Statistical properties

Concerns may be raised about the mathematical properties of estimates derived from the use of linear probability models. For example, Horrace and Oaxaca (2006) claim that predicted probabilities outside of the $[0, 1]$ interval indicate bias and inconsistency of the linear probability model regression estimates. For all regressions conducted in our paper, no predicted probabilities fall outside of this interval, assuaging this concern. Furthermore, the absence of negative predictions is not a product of chance: because the explanatory variables in our regressions are all categorical variables, the predictions are essentially proportions, rather than linear predictions from continuous variables. This helps to mitigate the usual criticism of the linear probability model.

Another issue is the relative rarity of the events (the driver-days where the dependent variable is equal 1 rather than 0). King and Zeng (2001) show that rare events cause estimated probabilities to be biased downwards for logit estimation (in the case where ones are rare relative to zeros). The level of the rare events bias is a function of the frequency of events relative to the total sample size: for example, a sample size of 1,000 with 2 events (0.2% of the sample) may suffer from rare events bias, but a sample size of 100,000 with 200 events (also 0.2%) may not. To examine whether rare events bias

¹⁴ Of these 15, 6 were for speeding, 6 were for red light violations, and 3 were mobile Bisson (2020).

potentially exists in our analysis, we conduct a simulation as follows. We set up a simulation using an effect size that is similar to the regression involving females but uses a much smaller sample size: if rare events bias appears absent, it should not be a concern of note in the real regression which has a sample 100 times larger. The simulation has 1,000 repetitions. For each, we generate a dataset with 43,390,582 observations where 0.00369% of observations in the pre-period have an event, and 0.004449% in the post-period. The effect size of interest is the difference between these two numbers which is 0.000759%. The results are as follows. We find no statistical evidence of rare events bias: the mean effect size of the simulations is also 0.000759% and the estimates are tightly distributed, with the 25th percentile being equal to 0.000620%, and the 75th percentile to 0.000889%. Moreover, the statistical power is healthy, with 30.1% of the samples producing statistically significant results for the effect size at the 0.001% level. This is despite the simulation using a sample size only one one-hundredth that of the sample used in the analysis. We conclude that it is unlikely that rare events bias is influencing the results in a statistically meaningful fashion.

7. Policy Discussion

This paper studies the impact of an increase in penalties for speeding on the number of tickets issued. It is important to study this question to improve the demerit point system and thus promote roadway safety. Our results provide the following policy implications.

First, we find clear evidence of deterrence. Increasing the number of points associated with certain violations decreased the likelihood of tickets issued for these violations. Drivers therefore respond to an increase in the severity of penalties.

Second, young males seem to react particularly strongly to such changes in penalties. Our model explains this result by using differences in risk aversion across gender. However, the model does not distinguish between different types of punishments which usually combine a fine and a number of points: the fine represents a short-term punishment, while the points increase the likelihood of losing one's license in the long-term. Our results could show that young males are particularly responsive to the threat of losing their license. A policymaker who wants to target young male offenders could choose to use demerit points since it seems a particularly salient punishment for this group. This result opens the door to a literature on the role of gender in deterrence. Males and females may be deterred differently by different types of punishments. To our knowledge, this literature is still nascent.

Finally, we document a significant spillover effect from the introduction of these new penalties. Even though excessive speeding events targeted by the law are relatively rare, the law appears to have influenced many drivers. Indeed, if the only reactions were from people usually speeding well above

	Logistic Regression				Linear Probability Model		
	Marginal Effect	Estimate	Standard Error	Sig.	Estimate	Standard Error	Sig.
Male Drivers (5,335,033,221 observations)							
Policy Indicator	-4.0341	-0.0762	0.0015	**	-4.1859	0.0763	**
Month 1	7.1421	0.1483	0.0047	**	8.6823	0.2761	**
Month 2	6.2501	0.1110	0.0046	**	6.6386	0.2726	**
Month 3	2.1713	0.0380	0.0048	**	2.2264	0.2683	**
Month 4	-5.1789	-0.0965	0.0049	**	-5.0416	0.2534	**
Month 5	-5.3990	-0.0969	0.0052	**	-4.5641	0.2379	**
Month 6	-6.6151	-0.1206	0.0047	**	-6.9509	0.2708	**
Month 7	-4.2401	-0.0782	0.0046	**	-4.4353	0.2648	**
Month 8	-6.4145	-0.1320	0.0049	**	-7.3088	0.2584	**
Month 9	-15.5015	-0.2503	0.0071	**	-6.6876	0.1737	**
Month 10	-22.1104	-0.3699	0.0057	**	-15.3145	0.2167	**
Month 11	-7.9256	-0.1366	0.0051	**	-7.2667	0.2609	**
Month 12	-1.5188	-0.0551	0.0047	**	-3.1070	0.2560	**
Female Drivers (4,340,212,273 observations)							
Policy Indicator	0.8374	0.0310	0.0022	**	0.8391	0.0611	**
Month 1	2.4421	0.1063	0.0070	**	3.5263	0.2238	**
Month 2	1.7784	0.0632	0.0069	**	2.2000	0.2191	**
Month 3	-0.4650	-0.0157	0.0074		-0.3857	0.2112	
Month 4	-4.3651	-0.1527	0.0078	**	-4.0417	0.1945	**
Month 5	-4.8962	-0.1654	0.0083	**	-3.9171	0.1824	**
Month 6	-4.6354	-0.1654	0.0071	**	-4.8207	0.2167	**
Month 7	-3.6293	-0.1390	0.0071	**	-3.9811	0.2116	**
Month 8	-4.3855	-0.1842	0.0074	**	-5.3036	0.2072	**
Month 9	-11.5890	-0.3584	0.0117	**	-5.3165	0.1302	**
Month 10	-16.5783	-0.5268	0.0095	**	-10.3117	0.1611	**
Month 11	-6.0985	-0.1978	0.0080	**	-5.2484	0.2036	**
Month 12	-0.9958	-0.0772	0.0072	**	-2.1935	0.2059	**

TABLE 7

Regressions with indicators for month since policy change

For each regression, the dependent variable is an indicator that a driver has committed any offence on a particular day. All regressions contain age category and demerit point category controls, as well as monthly and weekday indicator variables. The baseline age category comprises drivers under the age of 16. The heading "Sig." is an abbreviation for statistical significance, with the symbol * denoting statistical significance at the 0.1% level and ** the 0.001% level. In the linear probability model, coefficients and heteroskedasticity-robust standard errors are multiplied by 100,000.

the speed limit, we would likely not find statistically detectable effects in the overall sample, given the low share of tickets for excessive speeding (see Table 2). Overall, the legislation decreased the number of violations and caused people who habitually drive above the limit to speed less. This spillover effect is somewhat puzzling. Perhaps the excessive speeding law made people more aware of speeding penalties in general. Since drivers do not always pay

⁵³³ close attention to their speed, the threat of more severe penalties may have
⁵³⁴ increased their awareness for their speed in more mundane circumstances.

References

- Becker, G. (1968) "Crime and punishment: An economic approach," in F. N.G., C. A., and W. R., eds., *The economic dimensions of crime*, pp. 13–68, London: Palgrave Macmillan
- Benedittini, S., and A. Nicita (2009) "Deterrence, incapacitation and enforcement design. evidence from traffic enforcement in Italy," Technical Report n. 564, Università degli studi di Siena Quaderni del dipartimento di economia politica
- Bisson, B. (2020) "Radars photo: explosion du nombre d'amendes en 2019," *La Presse*
- Bourgeon, J., and P. Picard (2007) "Point record driving license and road safety: an economic approach," *Journal of Public Economics* 91, 235–258
- Castillo-Manzano, J. I., and M. Castro-Nuño (2012) "Driving licenses based on points systems: Efficient road safety strategy or latest fashion in global transport policy? A worldwide meta-analysis," *Transport Policy* 21, 191–201
- Crosen, R., and U. Gneezy (2009) "Gender differences in preferences," *Journal of Economic Literature* 47(2), 448–474
- Dionne, G., J. Pinquet, C. Vanasse, and M. Mathieu (2011) "Incentive mechanisms for safe driving: A comparative analysis with dynamic data," *Review of Economics and Statistics* 93(1), 218–227
- Gendreau, M. and Pichette, F. and Tardiff, F. (2011) "Dossier statistique bilan 2010 des taxis, des autobus, des camions lourdes et des tracteurs routiers," Technical report, SAAQ Société de l'Assurance Automobile du Québec
- Gong, B., and C.-L. Yang (2012) "Gender differences in risk attitudes: Field experiments on the matrilineal Mosuo and the patriarchal Yi," *Journal of Economic Behavior & Organization* 83(1), 59–65
- Hansen, B. (2015) "Punishment and deterrence: Evidence from drunk driving," *American Economic Review* 105(4), 1581–1617
- Helland, E., and A. Tabarrok (2007) "Does three strikes deter?: A nonparametric estimation," *Journal of Human Resources* 42(2), 309–330
- Horrace, W. C., and R. L. Oaxaca (2006) "Results on the bias and inconsistency of ordinary least squares for the linear probability model," *Economics Letters* 90(3), 321–327
- King, G., and L. Zeng (2001) "Logistic regression in rare events data," *Political Analysis* 9(2), 137–163
- Meirambayeva, A., E. Vingilis, I. Mcleod, and Y. Elzohairy (2014) "Road safety impact on Ontario street racing and stunt driving law," *Accident Analysis & Prevention* 71, 72–81
- Statistics Canada (2020) "Leading causes of death, total population, by age group, table: 13-10-0394-01 (formerly cansim 102-0561)," Technical report, Statistics Canada
- Transport Canada (2018) "Canadian motor vehicle traffic collision statistics: 2018," Technical report, Transport Canada