Incentive Mechanisms for Safe Driving: A Comparative Analysis with Dynamic Data

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Introduction

A major reason for the improvement of road safety in the OECD has been the development of incentives for safe driving. The road fatality rate decreased by 50% during the 15 years between 1978 and 1993 in Quebec and by 40% during the last 10 years in France.

Experience rating schemes used by the insurance industry have incentive properties (see Boyer and Dionne, 1989; Abbring et al., 2003).

They are supplemented by point-record driving licenses based on traffic violations and fines.

A point-record driving license was implemented in Quebec in 1978, together with a no-fault insurance regime for bodily injuries which replaced a tort system.

In Quebec, the *Société de l'Assurance Automobile du Québec* (referred to as SAAQ in what follows) is a public monopoly which provides coverage for bodily injury. The SAAQ is also in charge of accident prevention and control, including the management of driving licenses.

Before 1992, the rating structure for bodily injury insurance was completely flat. The public authorities in Quebec decided to implement an experience rating scheme based on accumulated demerit points, a reform applied from December 1, 1992 onwards.

This mechanism was added to other incentives, i.e., fines, the point-record driving license in force since 1978, and the private sector insurance pricing scheme for property damage.

This paper analyses the incentive properties of three incentive schemes: point-record driving license insurance pricing based on traffic violations and fines.

Literature review

Studies on incentive mechanisms for road safety have been discussed in the economic literature for many years (Peltzman, 1975; Landes, 1982; Boyer and Dionne, 1987).

Different empirical tests have been proposed to measure the effectiveness of such mechanisms for road safety (Sloan et al, 1995; Boyer and Dionne, 1989) or to measure the presence of residual asymmetric information problems in insurers' portfolios (Chiappori and Salanié, 2000; Dionne, Gouriéroux and Vanasse, 2001).

More recently, Abbring, Chiappori and Pinquet (2003) designed a new test based on the dynamics of insurance contracts to detect the presence of residual moral hazard.

Their model makes it possible to separate the moral hazard effect on accidents from unobserved heterogeneity.

Unobserved heterogeneity refers to non observed factors that affect traffic offences or accidents. In general unobserved heterogeneity results in positive occurrence dependence in the data.

Bad drivers, for unobserved reasons, are more likely to have accumulated offences in the past and to have offences in the future. The moral hazard test must then disentangle the negative dependence induced by incentives from the positive contagion (if any) in the data generated by unobserved heterogeneity.

They found no evidence of moral hazard in the French car insurance market.

The convex structure of the French "bonus-malus" system is used to show that the optimal effort level exerted by a rational policyholder increases after a claim at fault.

In our study, insurance pricing is not the major incentive scheme but rather a measure used to complement fines and the point-record driving license.

Moreover, the pricing scheme of the Quebec public automobile insurance is not strictly increasing and convex with respect to past demerit points but is increasing by steps.

Time effects are important in Quebec's point-record system, so we cannot apply directly the Abbring et al (2003) econometric methodology, because their model cannot separate adequately the time effect from the incentive effect.

Insurance pricing may not suffice as a tool for designing an optimal road safety policy since it may not create the appropriate incentives for reckless drivers (Sloan et al, 1995).

Bourgeon and Picard (2007) show how point-record driving license suspensions provide incentives for road safety among normal drivers (those who respond to the usual incentive schemes) when the judicial system or the insurance market fail to provide optimal incentives.

Point-record driving licenses also allow the government to incapacitate reckless drivers.

Fines do reinforce the effectiveness of the point record mechanism by providing more incentives to normal drivers.

With respect to the theoretical contribution of Bourgeon and Picard (2007), we shall test the prediction that the point-record driving license promotes road safety under moral hazard.

We shall also analyze the Quebec public insurance pricing scheme based on past convictions as a progressive fine. It can also be interpreted as a bonus-malus scheme.

Does this pricing scheme reduce moral hazard?

Other contributions on the measure of moral hazard

- **Dionne and St-Michel** (RE Statistics, 1991): Ex-post moral hazard in workers compensation;
- **Chiappori, Durand, and Geoffard** (EER, 1998): Ex-post moral hazard in the demand for physician services;
- **Finkelstein and McGarry** (AER, 2006): Evidence of moral hazard and adverse selection in long-term care insurance market;
- **Israel** (2007): Automobile insurance from experience rating schemes.
- **Dionne, Michaud, Dahchour** (2009): Separation of moral hazard from learning and adverse selection

Presentation of the data base and preliminary results

Our data base represents roughly one percent of the SAAQ portfolio.

The panel covers the period from January 1, 1983 to December 31, 1996.

A first sample of 40,000 license holders was selected at random at the beginning of 1983.

Then about 300 young drivers were added each following year.

Attrition rate is 1.5% and is not endogenous since the SAAQ is a monopoly and since it must supply insurance when the driving permit is active, the attrition rate must be low.

Test from a bivariate probit model of traffic offenses and departures from the sample was performed: correlation coefficient not significant at 5%.

The personal characteristics of each driver are available on the driving license for the current period.

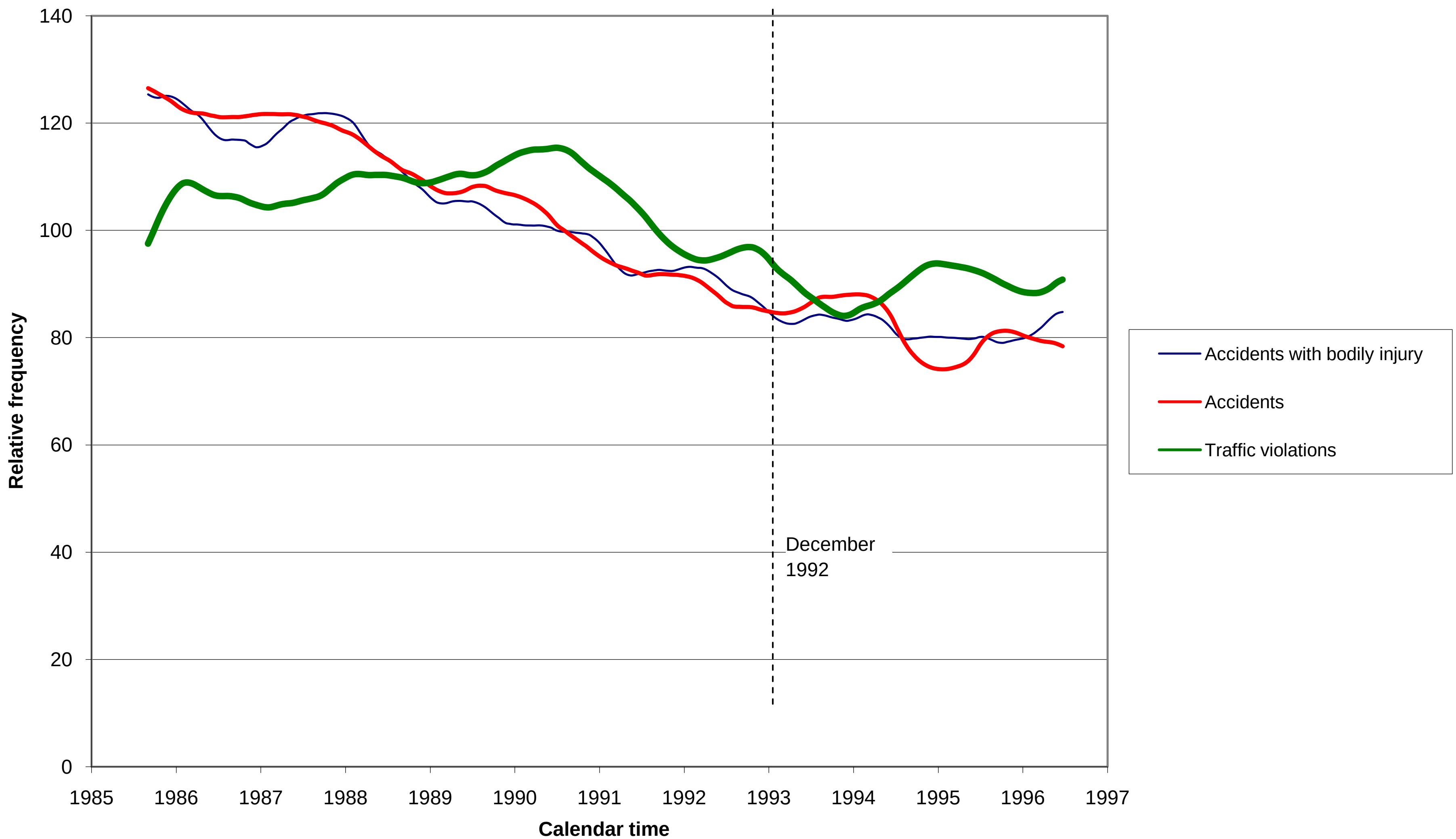
1) Accidents which have led to a police report.

2) Convicted violations of the Road Safety Code, together with the number of demerit points which are used in the point-record mechanisms. The number of demerit points is based on the severity of the traffic violation.

3) Driving license suspensions, which are spells rather than events.

4) Premium payments which since the 1992 reform are related to accumulated demerit points. These payments are made every two years at the policyholder's birthday.

Figure 1: Relative frequencies (in percentage) for traffic violations and accidents



On average, the annual frequency of traffic violations was equal to 17.6% before the reform and 15.4% afterwards, which corresponds to a 12.5% decrease. A multivariate analysis shows that the decrease is 15%.

The 1992 reform can be interpreted as a laboratory experiment to test whether an exogenous change in the use of memory reduces traffic violations.

We must emphasize that this decreasing result of traffic violations is not a moral hazard test.

Incentive effects of point-record mechanisms

Basic model for a point-record driving license without point removal

We suppose that the driving license is revoked when the driver reaches a total of N demerit points. In Quebec, 12 points before 1990; now 15.

A driver with a suspended driving license is reinstated after a period D with a fresh zero-point record like that of a beginner. The duration D may be fixed or random in the model. In Quebec, this is rather random.

A rational driver maximizes his expected lifetime utility expressed in $ and derived from:

- An instantaneous driving utility, d_u.
- A time-dependent disutility of effort, denoted as $e(t)$. This effort level is linked with an instantaneous traffic violation frequency risk, denoted as $\lambda(e(t))$. The hazard function λ is assumed to be a positive, decreasing and strictly convex function of the effort level.

In this section, we suppose that there is no point removal mechanism. In that case, the lifetime expected utility (we assume an infinite horizon) will depend only on the number *n* of accumulated demerit points. The Bellman equation on the expected utility leads to:

$$u_n = \frac{d_u}{r} - \frac{\lambda_*\left(u_n - u_{n+1}\right)}{r}, \left(0 \leq n < N\right)$$

where *r* is a discount rate, and where λ_* is defined as follows:

$$\lambda_*\left(\Delta u\right) \underset{\text{def}}{=} \min_{e \geq 0} e + \left[\lambda\left(e\right) \times \Delta u\right].$$

For instance, if the private disutility of driving license suspension is only the loss of driving utility during a period *D*, we have that:

$$u_N = \beta u_0, \beta = E\left[\exp\left(-rD\right)\right].$$

One can show that the optimal level of effort e_n is defined by:

$$\left(u_n - u_{n+1}\right) > -\frac{1}{\lambda(0)}$$

and is increasing in *n*.

Since fines and premiums are low in comparison to average wealth, we leave out risk aversion. With fines, incentives are effective if

$$e_n > 0 \Leftrightarrow u_n - u_{n+1} + \overline{fa} > \frac{-1}{\lambda'(0)}.$$

This means that the average fine is added to the utility loss in the argument of λ_*, which determines optimal effort.

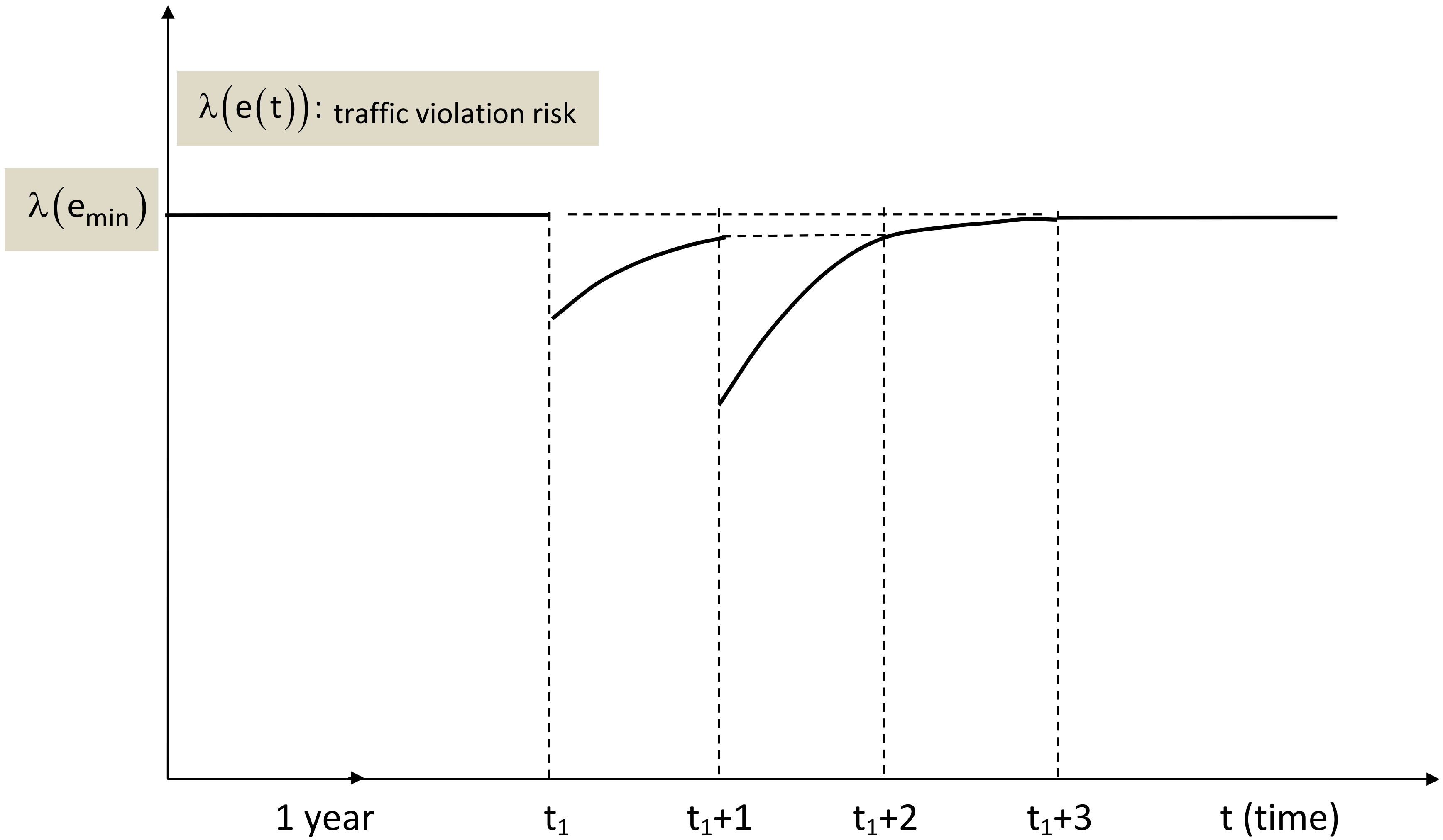
If fines are combined with the preceding point-record driving license, the optimal effort still increases with *n* for a given value of the average fine.

Point-record driving licenses with point removal

In Quebec, each traffic violation is redeemed at the end of a two-year period. Integrating this feature in the optimal behavior model is difficult, as all the seniorities of non-redeemed driving offenses must be included as state variables in the dynamic programming equations. Lifetime utility is expected to increase with time for a given number of demerit points accumulated, because the probability of having a suspension **decreases** with time.

Thus optimal effort should decrease with time. Optimal effort is then expected to increase with each traffic violation in order to compensate for the decreasing link between time and effort. On the whole, the incentive properties of the point removal system in force in Quebec are close to those of a mechanism without point removal when it comes to the number of demerit points accumulated.

Figure 2.—Time evolution of traffic violation risk related to optimal effort. Example with two traffic offenses.



Notes: The function $t \rightarrow \lambda(e(t))$ is represented by the thick line. In this example, the first traffic violation occurs at t_1, the second at t_1+1. The two demerit points are removed at t_1+2 and t_1+3. The optimal effort level is denoted as $e(t)$. It is determined by the seniority of non-redeemed traffic violations, if any. The minimum effort level is denoted as e_{min} and may be greater than zero, depending on the individual characteristics of the driver. After each traffic violation, there is an upward jump in the optimal effort level and an implied drop in traffic violation risk. The continuous time effect of incentives compensates the event-driven effect (i.e. $e(t)$ decreases with t and $\lambda(e(t))$ increases). Before t_1, the effort level is minimal. It increases after the first traffic violation. The drop in traffic violation risk is the opposite of the unobserved heterogeneity effect. The effort is maximum after the second offence, and then we have $e(t_1+2)=e(t_1+1)$ at the time of the first point removal (one non-redeemed traffic violation with a one-year seniority in both cases). We also have $e(t_1+3)=e_{min}$ at the time of the second removal.

Incentive effects of premiums indexed on demerit points: The example of Quebec

Table 1 presents the rating structure enforced for each driving license on the first contract birthday following December 1, 1992.

Table 1:—SAAQ insurance premiums for bodily injury as a function of accumulated demerit points since the last contract birthday

Accumulated demerit points (last two years)	Premium for the next two years (Canadian $)	Frequency (%)
0,1,2,3	50	93.7
4,5,6,7	100	4.9
8,9,10,11	174	1.1
12,13,14	286	0.2
15 and more	398	0.1

In this section, the incentive properties of this rating structure are analyzed separately from the point-record driving license.

Because of the local non-convexity of the premium, the incentives may not always increase with the number of demerit points accumulated.

Let us consider for instance a policyholder just before her contract birthday. The incentive level will be stronger with two accumulated demerit points than with four.

$$f_1 = 4.71\%;\ \ f_2 = 52.32\%;\ \ f_3 = 38.34\%;\ \ f_4 = 2.83\%;\ \ f_5 = 1.80\%.$$

Let us design an optimal behavior model based on this rating structure. Once the premium is paid, the driver is reinstated with a fresh zero point record.

Empirical results on the incentive effects of point-record mechanisms

Point-record driving license

In this section, we analyze the data before the 1992 reform which introduced the experience rating scheme based on demerit points.

Thus the point-record driving license interacts only with fines. We try to obtain a confirmation of the theoretical findings of Sections 3.2 and 3.3 (i.e., the effort level increases globally with the number of demerit points accumulated and decreases with the seniority of non redeemed traffic violations, if any), and to confirm the presence of moral hazard in the data.

A proportional hazards model (Cox, 1972) is used to estimate these hazard functions. We retained the following specification:

$$\lambda_i^j(t) = \exp\Big(\big(x_i(t)\beta_j\big) + g_j\big(adp_i(t)\big)\Big) \times h_j^{S_i(t)}\big(c_i(t)\big).$$

- $\lambda_i^J(t)$ is the hazard function of type *j* (j = 1: traffic violation or *j* = 2: accident) for driver *i* at calendar time *t*.
- Regression components which do not refer to the individual driver record are denoted by the line-vector $x_i(t)$.
- We retained the gender, driving license class, place of residence, age of the driver and calendar effects related to years and months.
- The number of demerit points accumulated in the last two years is denoted as $adp_i(t)$, and a decreasing shape is expected for g_1 from the theoretical model of Sections 3.2 and 3.3.

- The baseline hazard functions $h_j^{S_i(t)}$ depend on the risk type j and on the stratum $S_i(t)$.
- There are two strata, depending on whether the variable $adp_i(t)$ is equal to zero or not.
- Lastly, contract time $c_i(t)$ is integrated into the baseline hazard function h_j.

The function c_i is set equal to zero at the beginning of the whole period. Then it is reset to zero at each event which triggers a variation of the accumulated demerit points (i.e., traffic violation or point removal).

This event-driven operation should eliminate interactions between calendar and contract-time effects for the stratum associated to adp > 0.

From the theoretical model in Section 3.3, we expect effort to increase with the number of demerit points accumulated, under moral hazard. This is globally true in Table 2, where the function g_1 decreases beyond seven points.

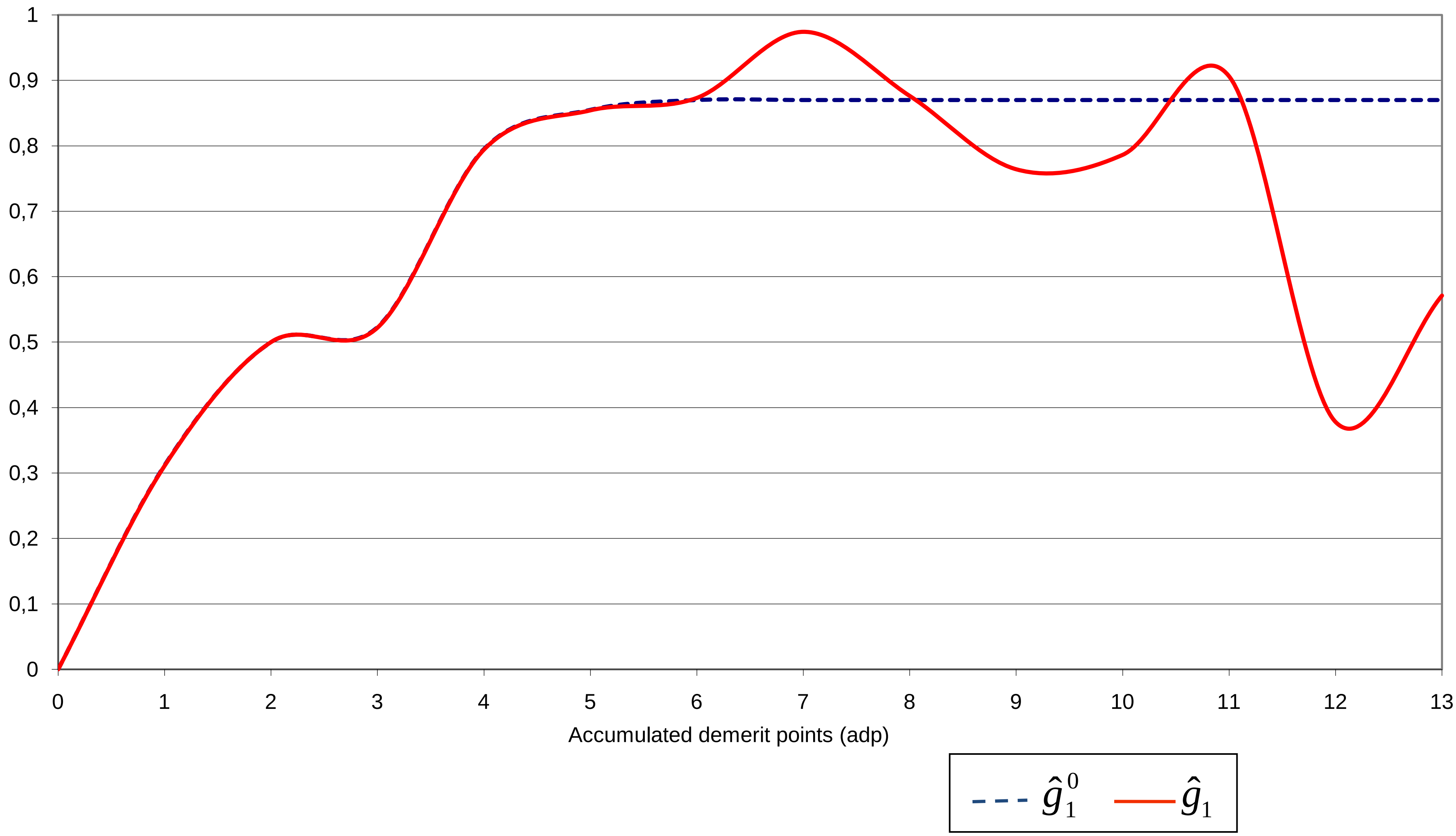
Table 2.—Estimation of the hazard function for traffic violation and accident frequency risks

Variable	Level	Frequency (%)	Traffic violation risk (g_1)	P-value (H0: $g_1(7) \leq g_1(adp)$, *adp* > 7)	Accident risk (g_2)
adp: Number of accumulated demerit points (last two years)	0 point (*)	76.60	0		0
	1 point	0.39	0.311		0.243
	2 points	9.36	0.500		0.328
	3 points	6.23	0.522		0.449
	4 points	1.92	0.794		0.496
	5 points	2.09	0.854		0.595

6 points	1.25	0.873		0.647
7 points	0.72	0.974		0.601
8 points	0.55	0.876	0.0130	0.736
9 points	0.43	0.764	< 0.0001	0.797
10 points	0.32	0.786	0.0002	0.842
11 points	0.06	0.906	0.2328	0.522
12 points	0.04	0.378	< 0.0001	0.810
13-14 points	0.04	0.571	0.0004	0.222

Notes: (*) is the reference level. Controlling for other variables, a driver with seven accumulated demerit points who gets a supplementary two point-offense has a traffic violation risk reduced by 1 - exp (0.764 - 0.974) = 19%. As the unobserved heterogeneity effect is increasing with *adp*, the estimated risk reduction due to the incentive effect is greater than 19%. The "p-values" refer to tests for the null assumption: $g_1(7) \leq g_1(adp)$ (with $adp > 7$) vs. the alternative, with one-sided rejection regions. For instance, the null assumption related to $adp = 8$ is rejected at the level α if α is greater than the "p-value" 1.3%, and accepted otherwise. The results suggest that g_1 is not increasing beyond $adp = 7$, which shows evidence of moral hazard. A global test for the increasing shape of g_1 is presented in Figure 3. Additional regression variables are: gender, driver’s license class (9 levels), place of residence (16 levels), age of the driver (5 slopes), number of past suspension spells (3 levels), as well as calendar effects related to years (8 levels), and months (12 levels). Number of observations: 3,492,868 pairs duration-event indicator, derived from 41,290 driver’s licenses. The durations are bounded above by one month.

Figure 3.—Global test for the increasing shape of the traffic violation risk as a function of accumulated demerit points



Notes: This figure presents a graphical test where the null is the weakly increasing shape of g_1 as a function of *adp*, the number of accumulated demerit points. The test statistic is a squared distance between the unconstrained estimation of g_1 (thick line) given in Table 2, and the set of weakly increasing functions of *adp*. The metric is that of the Wald asymptotic test, and the weakly increasing function which is closest to g_1 is represented by the dotted line. The statistic is equal to 43.18 and its asymptotic distribution is less than that of a $\chi^2(13)$ in the sense of first order stochastic dominance. This leads us to reject the increasing shape assumption for every significance level greater than 42×10^{-6}. As an absence of incentive effects entails an increasing shape for g_1 (unobserved heterogeneity effect), rejecting the null shows evidence of moral hazard.

Incentive effects of the 1992 reform and monetary equivalents for traffic violations and license suspensions

As already mentioned, a regression estimated from 1985 to 1996 with the covariates of Section 5.1 and a dummy related to the period following December 1, 1992 associates the reform with a 15% decrease.

Let us assess monetary equivalents for a traffic violation and a license suspension.

With $\lambda = 0.15$, the monetary equivalent of an additional traffic violation for these drivers belongs to the interval:

[$120, $195] if $r = 3\%$,

and to:

[$41.1, $55.7] if $r = 6\%$.

The monetary cost of a license suspension is bounded by:

$700 and $1,178 if $r = 3\%$,

and

if $\lambda_0 = 0.17$; $\lambda_1 = 0.17$; $\lambda_2 = 0.16$; $\lambda_3 = 0.15$; $\lambda_4 = 0.12$; $\lambda_5 = 0.09$.

Conclusion

Three important incentive mechanisms for road safety are used in Quebec.

The incentive effects of the point-record driving license increase with the number of demerit points accumulated. This confirms the presence of moral hazard in the data.

The point-record driving license acts as an incapacitating device for reckless drivers. Also, past suspension spells entail a significant reduction in the frequency of traffic violations and accidents.

Fines are on average the most efficient device.

The empirical results exhibit a rather uniform effectiveness after its enforcement in 1992, i.e., a 15% decrease in the frequency of traffic violations.

The SAAQ modified its rating policy in 2008, with a premium increase from the first demerit point. This should enhance the effectiveness of the premium schedule for the majority of drivers with a violation-free record.