Moral Hazard and Repeated Insurance Contracts *

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Abstract

We develop a model of repeated insurance contracts in a competitive market. The model focuses on the implications of two potentially important features of automobile insurance. First, individuals may exert effort to avoid accidents even though the effort is unobservable to insurance companies. Second, individuals have an incentive to hide accidents with minor damages by not filing a claim.

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These features imply that total claims in insurance data are affected by both individuals' effort and the probability of claims given an accident. We present some evidence on the relative importance of these two factors to observed changes in total claims.

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1 Introduction

Economic models of insurance contracts, beginning with Rothschild and Stiglitz (1976), have been used to study the problems of adverse selection and moral hazard that arise in insurance contracts. A substantial literature has developed that attempts to test the predictions of economic models of insurance by focusing on the prediction that high risk types will tend to purchase higher insurance coverage.[1] Cohen (2005) notes that recent studies using automobile insurance data, such as Chiappori and Salanie (2000), do not find any correlation between the choice of coverage and risk.[2] However, the complex nature of asymmetric information in insurance markets suggests that a full understanding of its effects requires a broad spectrum of evidence. In particular, direct evidence on the correlation between coverage and risk needs to be augmented by other forms of evidence.

A common feature of insurance contracts is the linking of the premium charged with the customer's past claims record in the form of discounts for good records and penalties for bad ones, usually referred to as experience rating in the literature. For insurance companies, experience rating can counteract the inefficiency arising from moral hazard. In the case of automobile insurance, the insurer generally cannot observe the precaution individuals take to avoid accidents, but can use an individual's past experience as a proxy for the risk the individual represents. By penalizing those

[1] See, Cohen (2005) for a recent review of the literature in testing insurance models

[2] See DeMaza and Webb (2001), Chiappori et al. (2002) and Finkelstein and MaGarry (2003)

with a bad claims record the insurer provides individuals an incentive to exert effort to avoid accidents. This type of behavior has received considerable attention from economists. Several papers have addressed the issue of how repeated contracts can help eliminate the moral hazard in insurance markets.[3]

One consequence of experience rating that has received much less attention is that in an asymmetric information world where insurance companies observe only claims, experience rating results in under-reporting of accidents. Knowing that making a claim will lead to a rate increase in the future, individuals will balance the benefit from claiming a loss against the cost of higher future premiums in determining whether to file a claim after an accident. As a result, some accidents are not claimed. These unclaimed accidents are usually referred to as "hiding accidents" or "missing insurance claims" in the insurance industry. The phenomenon of hiding accidents is well-known to the insurance industry, but has received little attention from economists. A theoretical analysis in Hosios and Peters (1989) features one insurer, one insured who can be of high or low risk type, and one level of damage. However, since their model does not allow for different levels of damage, it cannot address the hypothesis in the insurance industry that hiding accidents are mainly those involving minor losses.[4]

In this paper we develop a competitive insurance market model in which both the incentive to exert costly effort and to hide accidents can be jointly analyzed. In the model, insurance companies and individuals of two risk types interact over two periods in a competitive market. Insurance companies set premiums to maximize profits. Individuals who file a claim in period one may be treated differently from those who do not. Knowing this, individuals choose how much costly effort to expend in avoiding accidents and decide whether to file a claim after an accident. The model predicts

[3]See, for example, Rubinstein and Yaari (1983), Radner (1981; 1985).

[4]Cohen (2005) provides an empirical analysis of a related phenomenon where, in a world where claims made with one insurance company are not perfectly observed by another company, drivers with a large number of claims may attempt to hide this by switching insurance companies.

that individuals take care to reduce losses even if their precaution is unobservable to insurance companies. Moreover, individuals file a claim for damages only when the loss from an accident is above a cut-off value. As a result, the distribution of claimed losses is a truncation of the distribution of actual losses.

The comparative statics of the model reveal that a variety of exogenous factors that increase insurance companies' costs, and thereby increase insurance premiums, have the effect of reducing insurance claims. The reduction in claims can be attributed to two factors: individuals have an incentive to increase effort level to avoid accidents leading to a decline in total accidents, and the cut-off point for filing claims increases leading to fewer claims per accident. Exogenous factors that increase insurance companies' costs also increase the spread between premiums paid by individuals with good claims record and those with bad claims record. Auto insurance data from Ontario, over a period in which major legislative changes occurred is used to test the comparative static predictions of the model and to provide an alternative form of evidence on the importance of asymmetric information in insurance markets.

The remaining part of this paper is developed as follows: Section 2 introduces the basic model, and characterizes the competitive equilibrium. In Section 3 we examine the comparative statics of the model. Section 4 presents the results of the empirical tests of the main predictions of the model. The results are then discussed in relation to the previous literature. Section 5 concludes with a summary of the main findings.

2 The Basic Model

The insurance market modeled here has no barriers to entry and exit. Firms are identical in technology and cost, and engage in price competition to maximize profits. We assume firms do not offer different price-quantity bundle to screen high-risk from low-risk type. This assumption is made in response to the findings of no information advantage for insured in recent empirical literature, such as Chiappori and Salanié (2000), Cardon and Hendel (2001), Dionne, Gouriéroux, and Vanasse (2001) and Dahchour and Dionne (2002), none of which has found any evidence supporting the adverse selection hypothesis.

There is a continuum of individuals insured that are identical except for their probabilities of having an accident. Based on these probabilities, individuals can be sorted into two types: the high-risk type (Type h) that accounts for proportion α of the population, and the low-risk type (Type l) that accounts for proportion $(1-\alpha)$ of the population. The proportion of the two types is common knowledge and known to all agents in the market. Initially, neither individuals themselves nor insurance companies know an individual's type.[5] However, as individuals accumulate accident experience, they will have a better idea of their true types than insurance companies. Each individual has a von-Neumann Morgenstern utility function and is endowed with initial wealth W at the beginning of each period. The per period utility function $U(\cdot)$ is strictly increasing and strictly concave. An individual's total expected payoff v_i is the sum of payoffs received in the two periods,

$$v_i = E[U(W_1)] + E[U(W_2)],$$

where W_1 and W_2 are (respectively) his disposable wealth in period one and two after realization of the state of nature. Insurance is compulsory, but individuals are free to purchase a policy from any company.[6] Insurance companies issue insurance policies and reimburse their clients for any losses from an accident.

An individual chooses effort level $e \in [0, 1]$ to lower the chance of an accident and is free to decide whether to file a claim after an accident. The probability of accidents depends on both the individual's type and effort level; more care taken reduces the chance of having an accident. Let the probability of having an accident for a Type h individual with effort level e be $\pi_h(e)$ and for Type l be $\pi_l(e)$. Assume the probabilities

[5] Note that this assumption is made for simplicity and relaxing it does not affect the main results.

[6] Mandatory auto insurance is a common feature in the auto insurance markets of developed countries. Some jurisdictions use a public system of provision, but many important markets have free entry and competition between insurance companies.

of having an accident satisfy the following conditions,

$$\begin{aligned}
&\pi_h(e) > \pi_l(e) \quad \text{for all } \; e, \\
&\pi_i(0) < 1 \quad \pi_i(1) > 0 \qquad \forall i = h, l, \\
&\pi_i'(e) < 0 \; \forall e \in [0,1), \qquad \pi_i'' > 0 \quad \text{and } \; \pi_h'(e) = \pi_l'(e) \text{ for all } e, \\
&\pi_i'(0) < 0 \quad \text{and } \; \lim_{e \to 1} \pi_i'(e) = 0.
\end{aligned} \tag{1}$$

That is, the low-risk type is less likely to have an accident than the high-risk type when they both put into the same effort e, but the marginal effect of additional effort on the likelihood of having an accident is the same for the two types.

The actual losses A in an accident follow a continuous distribution with *cumulative distribution function* $F(\cdot)$ over the interval $\mathscr{A} \equiv [0, \kappa]$, where κ is the maximum damage that could occur to an individual in an accident. Let $\bar{A}$ be the *expected* value of damages,

$$\bar{A} = E[A] = \int_0^{\kappa} x \, dF(x).$$

The occurrence of accidents is initially known only to the insured individuals themselves and not directly observed by insurance companies. However, if a claim is filed it becomes common knowledge and known to all insurance companies in the market. Claimed losses can be perfectly verified by the insurance companies; therefore, only true damages is claimed and insurance fraud does not occur.[7]

With no insurance, per period expected utility for an individual of type i, exerting effort e would be

$$\pi_i(e) \int_0^{\kappa} U(W - x) \, dF(x) + (1 - \pi_i(e))U(W) - c(e),$$

where $c(e)$ is the utility cost of exerting effort e. We assume

$$\begin{aligned}
&c(0) = 0, \quad c'(e) > 0 \quad \text{for all } \; e > 0, \\
&c'(0) = 0 \quad \text{and } \; c''(\cdot) > 0.
\end{aligned} \tag{2}$$

[7]One issue that has received some discussion in the literature is possible fraud from soft tissue injuries that are hard to verify. We abstract from issues of fraud in this paper.

However, an individual does not know his type, so if q is the probability that the individual attaches himself to being of the high-risk type, his expected utility without insurance in that period is

$$\{q\pi_h(e) + (1-q)\pi_l(e))\} \int_0^{\kappa} U(W-x)\, dF(x) +$$
$$\{q(1-\pi_h(e)) + (1-q)(1-\pi_l(e))\}U(W) - c(e).$$

In fact, in period one individuals are required to purchase insurance at a price P, and have the option of not reporting an accident. As shown below, the optimal strategy for an individual in period one is to report any loss greater than a cut-off level, A^*, and not to report if the loss is below A^*. Let $\bar{F}(\cdot) = 1 - F(\cdot)$. We can express the period one payoff for an individual with effort level e_1 and claim cutoff A_1^* as

$$\{\alpha\pi_h(e_1) + (1-\alpha)\pi_l(e_1))\} \left\{ \int_0^{A_1^*} U(W-P-x)\, dF(x) + \bar{F}(A_1^*)U(W-P) \right\}$$
$$+\{\alpha(1-\pi_h(e_1)) + (1-\alpha)(1-\pi_l(e_1))\}U(W-P) - c(e_1).$$

An individual who had an accident and filed a claim in period one has a period two payoff of

$$\{q_1\pi_h(e_2) + (1-q_1)\pi_l(e_2))\} \left\{ \int_0^{A_2^*} U(W-P_c-x)\, dF(x) + \bar{F}(A_2^*)U(W-P_c) \right\}$$
$$+\{q_1(1-\pi_h(e_2)) + (1-q_1)(1-\pi_l(e_2))\}U(W-P_c) - c(e_2),$$

assuming he chooses (e_2, A_2^*) in period two. Here P_c is the premium he is charged in period two if he had a claim in period one and q_1 is his updated belief of being type h that would follow from having an accident in period one. The probability that this occurs, as a function of an individual's period one choices, is $\{\alpha\pi_h(e_1) + (1-\alpha)\pi_l(e_1)\}\bar{F}(A_1^*)\}$, as he does not know his true type. For an individual knowing his own type, the probability is simply $\pi_i(e_1)\bar{F}(A_1^*))$ for $i = h, l$.

The period two payoff for an individual with an unreported accident in period one is

$$\{q_1\pi_h(e_2) + (1-q_1)\pi_l(e_2))\} \left\{ \int_0^{A_2^*} U(W-P_n-x)\, dF(x) + \bar{F}(A_2^*)U(W-P_n) \right\}$$
$$+\{q_1(1-\pi_h(e_2)) + (1-q_1)(1-\pi_l(e_2))\}U(W-P_n) - c(e_2),$$

where P_n is the premium he is charged if he had no claims in period one. This occurs with probability $\{\alpha\pi_h(e_1) + (1-\alpha)\pi_l(e_1)\}F(A^*)$.

Finally, the period two payoff for an individual with no accident in period one is

$$\{q_0\pi_h(e_2) + (1-q_0)\pi_l(e_2))\}\left\{\int_0^{A_2^*} U(W-P_n-x)\,dF(x) + \bar{F}(A_2^*)U(W-P_n)\right\}$$
$$+\{q_0(1-\pi_h(e_2)) + (1-q_0)(1-\pi_l(e_2))\}U(W-P_n) - c(e_2),$$

where q_0 is his updated belief of being type h given that he had no accident. This occurs with probability $\alpha(1-\pi_h(e_1)) + (1-\alpha)(1-\pi_l(e_1))$.

An implicit assumption in the above formulation is that effort affects the probability of accidents but not the amount of damage and that the distribution over possible damages is independent of risk types. This in turn means that each individual in period two will update his own belief about his risk type on the basis of whether or not he had an accident, but not on actual losses.

Insurance companies set premiums to maximize profits. As an individual's claims history is common knowledge, insurance companies will have the same information about each potential insured. They offer the same period one premium P for all customers, and offer a pair of period two premiums: P_n for those with no period one claims, and $P_c(A)$ for those with a claim of size A. Free entry, plus the fact that every company (including any new entrant) has the same information about any potential customer, implies that the contract written with any customer in any period must earn zero expected profits. Let m_n and $m_c(A)$ be the period two beliefs of insurance companies that a customer with no period one claims and with a period one claim of A, respectively, is of the high risk type. Zero profit condition implies period one premium P must satisfy

$$P = \frac{1}{1+r}\{\alpha\pi_h(e) + (1-\alpha)\pi_l(e)\}(\Gamma(R,F)+\delta), \tag{3}$$

where r is the market interest rate. We assume insurance companies collect premiums at the beginning of period, which can be invested in the capital market at interest rate r, and pay damages at the end of period. Here δ is the administrative cost the insurance company incurs for each claim handled,[8] e is the effort level an individual takes in period one, and Γ is the expected damage that will be reported by a customer who makes a claim. The expected damage Γ depends on the period one strategies of customers as regards making claims (denoted as R), as well as on the distribution of actual damages, F. This is one means by which the choices of customers influence choices by insurers, the other one being the level of care chosen by individuals, e.

In period two, individuals with same claim history take the same level of effort, irrespective of their accident experience. This follows from our assumptions that the marginal effect of additional effort on the probability of accidents and the disutility from additional effort are the same for both types. Under these conditions, beliefs about one's type have no effect on the effort level e. If we let e^c and e^n, respectively, be the effort levels of those with and without a claim in period one, then the period two premiums offered to an individual must satisfy

$$\begin{aligned} P_n &= \frac{1}{1+r}\{m_n\pi_h(e^n) + (1-m_n)\pi_l(e^n)\}(\Gamma(R,F)+\delta), \quad \text{and} \\ P_c(A) &= \frac{1}{1+r}\{(m_c(A)\pi_h(e^c) + (1-m_c(A))\pi_l(e^c)\}(\Gamma(R,F)+\delta). \end{aligned} \tag{4}$$

To exclude the case that individuals might have zero disposable income, we assume

$$\frac{\pi_h(0)\,(E[A]+\delta)}{1+r} < W.$$

Because individual customers do not know their own types, they will all use the same reporting strategy in period one, and this in turn implies that the size of the reported claim conveys no information about their type.[9] Hence we can simplify insurance companies' beliefs for customers with a period one claim to $m_c(A) = m_c$ and the corresponding period two premiums to P_c.

[8] The Insurance Bureau of Canada reported that operating expenses to net premium ratio to be about 32% for the private insurers in Canada (auto and property insurance combined). de Meza and Webb (2001) report that expenses accounts for around 25% of premium income for auto insurance and 37% of premium income of property insurance in the UK from 1985 and 1995.

[9] In fact, under the assumptions of this section, even if individuals had known their true types, they would still use the same cut-off point A^*.

Given the assumption of compulsory insurance and price-competition only, it is clear that there exists at least one equilibrium. In below we outline an equilibrium in which individuals use a cut-off reporting rule in filing claims.

In the *equilibrium with a cut-off reporting rule*, individuals use a cut-off rule in deciding whether to claim for an accident. That is, there exists $A^* \in [0, \kappa]$ and a reporting rule $R : [0, \kappa] \rightarrow \{c, n\}$ such that an individual's reporting strategy is

$$R(A) = \begin{cases} c & if\ A \geq A^* \\ n & otherwise. \end{cases} \tag{5}$$

Hence a strategy for an individual in the two periods can be summarized by the two pairs, $(e_1, A_1; e_2, A_2) \in [0, 1]^2 \times [0, \kappa]^2$.

The equilibrium with a cut-off reporting rule consists of the following components:

(i) Individuals' effort level and cut-off point for claims, (e_1^*, A_1^*) in period one, and (e_{2n}^*, A_{2n}^*) in period two for those without claims in period one and (e_{2c}^*, A_{2c}^*) for those with a claim in period one. Choices of $(e_2^*, A_2^*; e_{2c}^*, A_{2c}^*)$ and $(e_1^*, A_1^*; e_{2n}^*, A_{2n}^*)$ maximize the total payoffs of an individual with and without a period one claim, respectively.

(ii) Premiums (P, P_n, P_c) satisfy the zero profit condition in (3) and (4).

(iii) The belief q_0 and q_1 is derived from the prior, α, and an individual's accident history using Bayes rule, while m_c and m_n is derived from α and an individual's claims history using Bayes rule,

$$\begin{aligned} q_0 &= \frac{\alpha - \alpha\pi_h(e_1^*)}{1 - \alpha\pi_h(e_1^*) - (1-\alpha)\pi_l(e_1^*)}\ , \\ q_1 &= \frac{\alpha\pi_h(e_1^*)}{\alpha\pi_h(e_1^*) + (1-\alpha)\pi_l(e_1^*)}\ ; \end{aligned} \tag{6}$$

$$\begin{aligned} m_c &= \frac{\alpha\pi_h(e_1^*)\bar{F}(A_1^*)}{\alpha\pi_h(e_1^*)\bar{F}(A_1^*) + (1-\alpha)\pi_l(e_1^*)\bar{F}(A_1^*)}\ , \\ m_n &= \frac{\alpha - \alpha\pi_h(e_1^*)\bar{F}(A_1^*)}{1 - \alpha\pi_h(e_1^*)\bar{F}(A_1^*) - (1-\alpha)\pi_l(e_1^*)\bar{F}(A_1^*)}\ . \end{aligned} \tag{7}$$

Individuals will not be in the market after period two, so it is optimal to have $A_2^* = 0$ and to claim for any losses. Moreover, since the premium an individual pays is solely determined by his claims history in period one, there is no payoff to care taken in period two; it is individual's best response to choose $e_2^* = 0$. This is not only true in the equilibrium with a cut-off reporting rule, but also true in any equilibrium. Hence individuals play a strategy such that $e_2^* = 0$ and $A_2^* = 0$ irrespective of their accident and claims experiences. We will therefore henceforth drop the subscript from the choice of e in period one, and take their period two decision as given.

As insurance companies may charge different premiums depending on individual's period one claims record, he may not claim after an accident with damage of A. If he files a claim, his total payoff would be

$$U(W-P)+U(W-P_c)-c(e).$$

where $c(e)$ is his disutility from taking effort in period one. If he decides not to file a claim, his total payoff in the two periods would be

$$U(W-P-A)+U(W-P_n)-c(e).$$

He claims when

$$U(W-P)+U(W-P_c) > U(W-P-A)+U(W-P_n), \tag{8}$$

and does not claim when

$$U(W-P)+U(W-P_c) < U(W-P-A)+U(W-P_n). \tag{9}$$

If the damage just equals his cut-off point A^*, he is indifferent between claiming and not claiming,

$$U(W-P)+U(W-P_c) = U(W-P-A^*)+U(W-P_n).$$

An intuitive result is that in this equilibrium, the premium paid by those with a claim in period one is higher than that paid by those without claims in period one.

Lemma 1. *In equilibrium,* $P_c > P_n$.

The proof is provided in the Appendix.

As $P_c > P_n$, it follows immediately that in equilibrium, A^* is strictly positive but less than κ. To see why it is true, note that for damage A very close to zero we would have

$$U(W-P)+U(W-P_c)<U(W-P-A)+U(W-P_n).$$

However, for some damage just below κ we would have

$$U(W-P)+U(W-P_c)>U(W-P-A)+U(W-P_n).$$

The Intermediate Value Theorem implies that there exists $A^* \in (0,\kappa)$ such that

$$U(W-P)+U(W-P_c)=U(W-P-A^*)+U(W-P_n). \tag{10}$$

An individual claims if $A \geq A^*$, and does not claim if $A < A^*$.

Insurance companies observe only claims but not whether a client has an accident. If an individual choose not to claim after an accident, insurance companies will have different beliefs about his type from his own.

Claim 1. *In equilibrium the belief of insurance companies about an individual is different from the belief of the individual's own. In particular,*

$$q_1 = m_c > m_n \qquad \textit{and} \qquad q_0 < m_n.$$

The intuition for this result is as follows.[10] Since insurance companies know that some individuals with no claims record may actually have had an accident in period one, they will think, quite reasonably, that an individual without claims may actually have an accident in period one. Consequently their updated belief, m_n, of an individual with no claims record will be greater than the individual's own belief if he had no accident in period one, and smaller if the individual had an unclaimed accident. This pooling of information benefits those who hid an accident in period one and penalizes those who in fact had no accident in period one. An individual with no accident in

[10]The proof is given in the Appendix.

period one ends up paying a higher second period premium than he otherwise would have had the insurance companies been able to distinguish him from those with unclaimed accidents, whereas an individual with an unclaimed accident ends up paying a lower premium than he otherwise would.

Given insurance premiums P, P_n, P_c, the expected utility for an individual who is unaware of his own type and chooses (e, A) in period one and $(0, 0)$ in period two equals

$$v = (\alpha\pi_h(e) + (1-\alpha)\pi_l(e))M + [U(W-P) + U(W-P_n)] - c(e), \tag{11}$$

where

$$M = \int_0^{A^*} U(W-P-x)\,dF(x) - F(A^*)U(W-P) + \bar{F}(A^*)[U(W-P_c) - U(W-P_n)]. \tag{12}$$

We now summarize the main results on equilibrium behavior with the following proposition.

Proposition 1. *In competitive equilibrium, individuals act in such a way that $e^* > 0$ and $A^* > 0$ in period one while $e^* = 0$ and $A^* = 0$ in period two. Insurance premiums satisfy the conditions in (3) and (4). And the belief of individuals and insurance companies' satisfy (6) and (7) respectively.*

Therefore, in the equilibrium with a cut-off reporting rule, individuals take care to lower the chance of accidents in period one even though this effort is costly and unobservable to insurance companies. Moreover, they may not file a claim after an accident has occurred in period one; accidents with small damages are not claimed. As it turns out, this is also the unique equilibrium in out model.

Claim 2. *The equilibrium with a cut-off reporting rule is the only competitive equilibrium.*

Note that the model analyzed here is closely related to the career concern literature (e.g. Holmström, 1999). There, managers of different types caring about future payoffs exert effort to enhance their current performance in order to prevent their true types from being revealed. However, there is one important difference between our model and those used in career concern literature: there is no analog to hiding accidents in that literature. It is assumed that all agents observe the same signals of the performance of managers at the same time.

3 Comparative Static Results for Driver Behavior

The competitive multi-period insurance market model has a number of comparative static predictions which can be used to assess how useful such a model might be in explaining patterns in the data. The model distinguishes between claims filed with insurance companies and accidents that have actually occurred and comparative statics are derived for both claims and accidents. In Section 2, we showed that in equilibrium, individuals may choose not to file a claim after an accident, pretending to be less risky than they truly are. This prediction has important empirical implications. The data available from insurance companies reflect total claims, not necessarily total accidents. It is important to know how much of any change in total claims are the result of changes in total accidents as opposed to changes in claims behavior. It remains an open question as to how sensitive a driver's precautionary effort level is to the parameters of the insurance contracts that are present in the automobile insurance market. More specifically, do insurance companies in a competitive environment influence driver behavior by changes in the parameters of the equilibrium contracts they offer?

A key exogenous parameter of the model is the insurance company cost factor δ, representing the cost of covering losses, monitoring expenditures and other administrative costs. Insurance companies frequently cite the downturn in investment market, increase in reinsurance rate after 9/11 as causes of the increase in insurance premiums after 2001. Other cited influences are court judgements, the laws governing insurance and the ability to sue, and government tax policy.[11] Revenues for the insurance companies in the model are affected by the return on investment given by the exogenous interest rate parameter, r. The decrease in revenues following the major decline in investment returns after the recent stock market crash is often cited as a reason for higher insurance rates after 2000.

Claim 3. *An increase in δ leads to an increase in the premium spread as well as increases in all premiums,*

$$\frac{dP_c}{d\delta} > \frac{dP_n}{d\delta} > 0. \tag{13}$$

Changes in δ affect the second period premiums paid by individuals with or without a claim in period one, but have larger impacts on the premium for those with a period one claim. That is, there is an increase in the premium spread between drivers with and without a period one claim. This is true mainly because those with a claim in period one are more risky and therefore, more likely to file a claim in period two.

An increase in δ also affects the precautionary effort level of drivers and their cut-off point, via its effect on the premium spread.

Claim 4. *An increase in the premium spread ($P_c - P_n$) will increase the precautionary effort level e^* and the damage cut-off point to file a claim, A^*.*

This result is intuitive. As the spread between premiums for drivers with and without a period one claim increases, a claim necessarily becomes more costly from an individual's point of view and thus, the benefit from claiming must also increase. This in turn implies a higher cut-off point in making claims. Similarly, an increase in the premium spread is equivalent to an increase in the cost of having an accident which in turn, increases the marginal benefit from extra care. As the marginal cost function remains unchanged while the marginal benefit of precautionary effort goes up, effort increases to ensure the marginal benefit of precaution equals the marginal cost. The increase in the cut-off point also increases the average claims cost to insurance companies by truncating the lower tail of the distribution.

[11] See de Meza and Webb (2001) for more detailed discussion.

Claim 5. *An increase in δ results in an increase in the period one precautionary effort level e^* in equilibrium,*

$$\frac{de^*}{d\delta} > 0, \qquad \frac{dA^*}{d\delta} > 0.$$

The interesting comparative static result for an increase in the cost parameter, δ, is that it results in fewer claims for the insurance companies for two reasons: an increase in precautionary effort taken to avoid accidents and fewer accidents resulting in claims.

Inspection of the zero-profit conditions in (3) and (4) indicates that changes in the investment return parameter, r, have exactly the opposite effect of changes in δ. Thus, a downturn in the investment market results in fewer claims on insurance companies via two effects: a higher level of precautionary effort and a higher damage cut-off point.

4 Empirical Evidence

In contrast to the extensive theoretical literature on insurance markets, empirical testing of the theory has been rare until very recently. Chiappori and Salanié (2002) have criticized the development of large number of theoretical models in the literature without empirical support, and advocated developing theories hand in hand with empirical validations of the theory. The model of a competitive insurance market developed in this paper predicts that exogenous changes affecting insurance cost and revenues will have an impact on both driving behavior and claims behavior. In this section we provide some evidence on these predictions.

The data used are of two types. The Insurance Bureau of Canada (IBC) collects, and makes available to its members a set of standard statistics relating to claims, including the total number of claims and the average cost. These data provide a high level of detail on auto insurance in Canada. The evidence presented here focuses on the subset of data for drivers 25 years and over in the urban areas of the province of Ontario. This has several advantages for our analysis. First, it corresponds to a private insurance market where there is free entry for insurance companies. Second, it provides a large sample of drivers who were unaffected by special provisions made for younger drivers during the period. Third, there are a number of identifiable changes in the market that can be used as exogenous change points that affected insurance costs. Indeed, movements in the cost of automobile insurance has taken up a significant part of the political debate in Ontario in the last two and a half decades and resulted in four major legislative changes.[12] The IBC data set is the primary source for the empirical analysis. The second data source is the ”Automobile vehicle insurance premiums” component of the Consumer price index for Ontario (OCPI). This provides a measure of the price faced by drivers in Ontario for a standardized insurance product. The IBC data set also contains a related measure - the average premium paid by drivers.

4.1 Evidence on the Path of Premiums in Ontario

During the period 1990-2003 covered by the IBC data there were several major legislative changes affecting insurance costs, and hence premiums. In addition, in the most recent period insurance costs and returns were dramatically affected by a number of significant court cases and a sharp reduction in the income from invested premiums. The effects of these changes can be seen in the auto insurance premium component of OCPI.

In June 1990, Bill 68 (The Ontario Motorist Protection Plan) was passed. This was

[12] In Canada, auto insurance is compulsory for all vehicles operated in the road. Three provinces, British Columbia, Saskatchewan and Manitoba, have a public auto insurance system where drivers purchase the policy from a government operated insurance company at the time when they register their vehicles. Quebec has a semi-public system in which bodily injury coverage is provided by a public plan Société de l'assurance automobile du Québec (SAAQ) while property damage is covered by private insurer. The remaining provinces including Ontario have a private insurance system where all coverage is provided by private insurance companies.

introduced with the intention of reducing insurance costs. In fact, the OCPI series shows a step up from 92.3 in June 1990, to 99.6 in July 1990, but then it is stable right up to June 1993. By contrast, prior to Bill 68, the OCPI had been increasing rapidly, from and annual average of 58.6 in 1985 to 96.2 in 1990. In January 1994, Bill 164 was passed which is generally agreed increased insurance company costs, primarily by containing richer no-fault benefits than before and by expanding the right to sue for non-economic loss. The OCPI annual averages show the following path: 100.2 (1991), 100.0 (1992), 108.8 (1993), 126.6 (1994) and 143.0 (1995). In the monthly series there is a clear jump at the time of Bill 164 from 113.3 in January 1994 to 126.0 in February, followed by a continuing increase. Thus the periods 1991-1993 and 1994-1996 provide contrasting paths for the premium. The earlier period was one of stable premiums; the later period clearly had higher premiums that appear to be the result of legislative changes.

In November 1996 Bill 59 was passed with the intention of containing the rapidly rising insurance premiums. In fact, the OCPI shows a value of 174.4 in November 1996 and remains stable through to December 2001 which shows a value of 178.0. From December 2001, however, there is a rapid increase in the OCPI that is generally attributed to the decisions in some key court cases that raised insurance costs and to the dramatic decline in the return on invested premiums due to the downturn in investment market. Bill 198 was introduced in December 2002 in an attempt to stabilize insurance premiums, but its effect does not show up until late 2003 when premiums stabilize. The period from November 1996 thus provides contrasting paths for the premium, being stable in the earlier period and rapidly increasing in the later period.

The IBC data include a measure of the average premium paid by driver class and insurance coverage. There are three forms of insurance coverage: accident benefits (AB), third party liability (TP) and collision damage (CO). Data on Collision and Liability claims from the IBC are available for the period 1990 to 2003. However, data on AB claims is unfortunately only available for the period 1996 to 2003. Since AB and TP are mandatory, and CO is taken by the majority of drivers, the closest approximation to the OCPI premium series is obtained by summing the average premiums paid for each of the components in the IBC data. The IBC data on average premiums is not designed to be a measure of the cost of a standard insurance coverage; it is simply the average expenditure by drivers. Hence caution is necessary in comparing the IBC data with the OCPI. The comparison for the period beginning in 1996 when all three components are available in the IBC data shows a broad consistency with the OCPI. The data are presented for the three largest driver classes in Table 1. The main difference is that the OCPI shows stability rather than a decline following Bill 59 and the premium increases in the most recent period do not show up until a year later compared to the IBC series. Overall, however, the IBC data is consistent with similar contrasting periods of premium stability (or decline) with periods of increase that correspond with the legislative changes.

4.2 Statistical Tests Using the Frequency of Claims

The theoretical model of Section 2 specified the probability of having an accident, π. The π function is assumed to be the same for all individuals, but the value of π varies across individuals and time. Some of the determinants of π, the quality of the road, the safety features of the vehicles, the weather, the individual's type, are assumed to be beyond the control of the individual. However, as the model emphasizes, driver effort can affect the value of π and this is a function of the premium (spread). The specification adopted for the empirical analysis is that the probability of an accident in period t for a randomly chosen driver, from a fixed population with a fixed proportion of high and low type drivers, is

$$\pi_t = \pi(S_t, z_t) \tag{14}$$

where S_t is the premium spread, which determines the unobservable value of e and z_t captures all other factors such as the weather, safety features of the average vehicle, road quality, etc., which may change over time. Since data on the conditions each driver faces are in general not available, z_t is treated as unobservable. There is no direct measure of S_t so the model cannot be directly estimated. However, given two periods, t and $t+1$, where it is known that S_{t+1} is larger than S_t, the theoretical model implies that $\pi_t|z > \pi_{t+1}|z$. This prediction can be tested under certain conditions described below.

Given that an accident has occurred, an individual has to decide whether to file a claim. The results of the theoretical model show that, claims filing behaviour depends on S, through its effect on the cut-off point A^*. However, it also depends on other factors such as the damage distribution and co-operation from another driver if the accident involves more than one vehicle. The specification adopted for the empirical analysis is that the probability of a claim, conditional on an accident in period t is:

$$\omega_t = \omega(S_t, x_t) \tag{15}$$

where S_t is the premium spread, which determines the unobservable value of A^* and x_t captures all other factors such as repair costs which may change over time. Since data on the other factors are in general not available, x_t is treated as unobservable. Given two periods, t and $t+1$, where it is known that S_{t+1} is larger than S_t, the theoretical model implies that $\omega_t|x > \omega_{t+1}|x$.

Let I be the frequency of accidents, C be the frequency of claims, and W be the conditional frequency of claims, i.e.

$$I = \frac{(accidents)}{(policies)} \tag{16}$$

and

$$C = \frac{(claims)}{(policies)} \tag{17}$$

and

$$W = \frac{(claims)}{(accidents)}. \tag{18}$$

Note that I and W provide estimates of π and ω, respectively. However, the IBC data records only C, which provides an estimate of $\pi\omega$, i.e. $plim(C) = \pi\omega$. This does not permit tests of the individual predictions on π and ω, but since the direction of effect of the spread on π and ω is the same, it does permit a test of a joint prediction on the product, provided certain assumptions can be made on z and x.

The model in Section 3 is a simple two period model with comparative static predictions regarding the effects of S. In order to confront these predictions with the data, it is assumed that the periods of different premium "regimes" outlined above correspond to comparative static experiments. One further complication is the presence of unobservable variables, z and x, which are likely to change over the period.[13] In order to deal with this complication, the model's predictions are tested in a difference-in-difference framework. Consider two close periods denoted a and b, where a has an increasing premium (a regime change from low to high) and b has a stable premium (no regime change), and assume that a linear approximation, $\alpha_0 + \alpha_1 t$ can proxy the trend for z and x over the interval. In the period of the stable premium spread, there is no change in behaviour due to a change in the premium. In the period of an increasing premium, let the time path of the difference across periods in the effects due to effort and claims behaviour be given by $D(t)$. Then,

$$\pi\omega = \begin{cases} \alpha_0 + \alpha_1 t & if\ t\epsilon b \\ \alpha_0 + \alpha_1 t + D(t) & if\ t\epsilon a \end{cases} \tag{19}$$

The model predicts that $D(t)$ is decreasing. This can be tested by differencing the difference across the two regimes.

The prediction is tested using the IBC claims data for driver classes 1, 2 and 3, which are the largest groups in the data set.[14] Claims are reported separately for the three types of insurance, AB, TP and CO. However, AB and TP can only be used from 1996 on.[15] From the discussion above, the period 2001 to 2003 is an appropriate candidate for period a, and 1997-1999 is a period of equal length that is a good candidate

[13]Many elements of both z and x are likely to change over time, including road safety and vehicle safety, as well as health and repair cost.

[14]Claims data are reported separately for 11 classes of driver, based on demographic characteristics and miles driven. The precise definitions of the classes are provided in the Appendix.

[15]AB only became available in 1996; TP was available earlier, but the data are unreliable (missing)

for period b. Hence $D(2003) - D(2001)$ is given by:

$$\Delta D = (\pi_{2003}\omega_{2003} - \pi_{2001}\omega_{2001}) - (\pi_{1999}\omega_{1999} - \pi_{1997}\omega_{1997}) \tag{20}$$

and an estimate of the change in D is $(C_{2003} - C_{2001}) - (C_{1999} - C_{1997})$. The estimates are presented in the top part of Table 2.

The results for TP and CO show highly significant negative estimates for the change in ΔD. The results are also negative for AB, but the point estimates are smaller. The remaining results in Table 2 are for CO only due to the data constraints noted above. These present an additional contrast between the period of stability in 1991-1993 with the period of rising premiums in 1994-1996 following Bill 164. These show the same results for collision as for 2001-2003. There is thus, considerable support for the joint hypothesis that the premium increases affected precautionary effort and/or claims behaviour in the way the model predicted.

The potential importance of these results is investigated in Table 3. The top half of Table 3 compares the actual claim frequency, by insurance type and driver class, for 2003 with a counterfactual frequency calculated by applying the results in the top part of Table 2. Thus in 2003, the frequency of claims under third party coverage for drivers of class 1 was 0.0353, or 3.53 claims per 100 policies. The counterfactual frequency is calculated by increasing this claim frequency by the amount estimated in Table 2 for this group (0.0089) as the reduction in claims that resulted from the increase in S over this period. The percentage increase of the counterfactual from the actual claim frequency is given in parentheses. Thus, in 2003, for drivers of class 1, it is estimated that claims made under third party coverage would have been 25 percent higher. The increases are very similar for the remaining driver classes for third party coverage and for collision coverage. The bottom part of Table 3 repeats the counterfactual experiment for the earlier comparison period with collision coverage and shows the same type of result.

An interesting question is whether changes in claiming behaviour (ω) are more or

for 1993-1995.

less important than changes in precautionary effort (π). As noted above, the IBC data set records claims rather than accidents. However, a comparison of the three types of insurance coverage provides some indication of the likely decomposition of changes in ω and π because the possibility of hiding the accident from an insurance company is likely to be different for the different types of coverage. In particular, accidents involving personal injury are likely to be the most difficult to hide. Thus AB may serve as a proxy for total accidents as well as total claims.[16] Since TP involves another driver, it is probable that it is more difficult to hide the accident from an insurance company in the case of TP compared to CO, which only involves the potential claimant.

Applying the point estimates to the counterfactuals in Table 3 shows that in general the percentage increases for AB are smaller than for TP and CO. While the result for AB class 1 is similar to class 1 for TP and CO, all the other results show much smaller percentage increases for AB. Overall, the results in Table 3 are consistent with the hypotheses that both π and ω are reduced by a higher S. Comparison of the AB results with TP and CO suggest that most of the reaction is in ω. Changes in driver effort may be able to reduce accidents to some extent, but a large part of the reduction in claims appears to be due more to an increase in hiding accidents. Comparison of TP and CO shows similar results for both types of coverage, though the point estimates are larger for collision, suggesting that it is in fact easier to hide accidents for that type of coverage.

4.3 Discussion and Related literature

Most of the previous empirical literature has focused on the relation between insurance coverage and risk. The evidence presented in this paper relates to measures individuals can take either to avoid accidents or to prevent knowledge of an

[16]This is a similar approach to Levitt and Porter (2001) where fatality crashes are used as a proxy for total accidents in estimating the fraction of drinking drivers and the risks associated with drinking driving.

accident reaching insurance companies. The evidence on the phenomenon of hiding accidents suggests that asymmetric information is important in insurance markets. When there is an increase in the penalty that follows the revelation of an accident, individuals attempt to hide more accidents. This incentive to hide information from insurance companies is consistent with the evidence in Cohen (2005). In Cohen (2005) individuals claim after an accident, but try to hide their claim history by moving insurance companies. Cohen (2005) finds, for example, that the number of claims that policy holders self report to a new company for each past year prior to joining the new company is much smaller than the number of claims per year with the new insurer.

The previous literature has noted the difficulty in distinguishing between adverse selection and moral hazard. In particular, evidence based on the correlation between coverage and accidents cannot distinguish between the two. In the model of Section 2, moral hazard effects are seen most clearly through the reaction to changes in the premium spread. Since the observed data in general represent claims rather than accidents, it is difficult to test this response directly. However, the relatively low response for the AB claims, which are expected to be least affected by changes in claims behaviour, and therefore to most closely proxy accidents, suggests that the possibility of affecting accidents by varying care is quite limited - at least for moderate variation in expenditure on costly effort. This is consistent with the previous literature that has sought evidence on moral hazard. Abbring, Chiappori, and Pinquet (2003), for example, find no evidence of moral hazard in French automobile insurance data using a dynamic insurance model with experience rating. The magnitude of the response depends on the cost of effort and its effect on π as well as on the size of the penalty from the experience rating. The evidence thus far is consistent with the presence of moral hazard, but in an environment where the marginal effect of effort on accidents is small over the effort range induced by the penalties implied by experience rating.

5 Conclusion

In this paper we develop a model of a competitive insurance market designed to allow examination of the reaction of insured motorists to changes in the penalties they face if they have an accident. The two possible reactions to an increase in the penalties are: (i) to exert more costly effort to avoid an accident, and (ii) to hide accidents that involve a relatively small amount of damages from insurance companies. In the first part of the paper, we develop a model of a finitely repeated insurance contracts. We show that exogenous changes that increase insurance companies' cost and insurance premiums have the effect of reducing insurance claims. The decrease in claims can be attributed to two factors: a decline in accidents because of increased care by drivers, and a decline in the reported number of claims per accident.

In the second part of the paper, we test the predictions of the theoretical model using claims data for the province of Ontario using a difference-in-difference strategy. The results provide substantial evidence of driver reaction to an increase in the penalties they face after an accident in the direction predicted by the model. The results suggest that while some of the decline in claims in the periods of rising penalties may be due to drivers exercising more care to avoid accidents, most of the decline appears to be due to a reduction in the likelihood that a driver will file a claim if the damages are relatively small - the phenomenon of hiding accidents.

Appendix A

A-1: IBC Classification Descriptions

Class 01:Principal driver ages 25 or above, no male operator under 25, no unmarried female operator under 25 without driver training. For pleasure use only - no driving to work; annual distance of 16,000 km or less; 2 or fewer operators per automobile of whom has held a valid operator's license for at least the past 3 years.

Class 02: Principal driver ages 25 or above, no male operator under 25, no unmarried female operator under 25 without driver training. Driving to work 16 km or less one way permitted; annual distance not limited; 2 or fewer operators per automobile.

Class 03: Principal driver ages 25 or above, no male operator under 25. Driving to work over 16 km or less one way permitted; annual distance not limited; 2 or fewer operators per automobile

A-2: Data

Table 1: Automobile Insurance Premium Paths in the IBC and Ontario CPI data

year	IBC (c1)	IBC (c2)	IBC (c3)	OCPI
1996	7.41	9.53	9.91	151.9 (175.4)*
1997	7.07	9.08	9.59	175.0
1998	6.57	8.29	8.86	176.2
1999	6.27	7.82	8.4	176.6
2000	6.09	7.56	8.07	177.2
2001	6.37	7.86	8.33	177.2
2002	6.97	8.75	9.33	195.0
2003	8.09	10.49	11.08	274.3

Notes: IBC (class x) is the average premium paid by drivers of class x.

* The OCPI are the calender year annual averages. The November CPI for 1996 when Bill 59 was introduced was 175.4.

Table 2: Difference in difference tests

$\Delta D = (2003-2001)-(1999-1997)$					
Third party Liability			Accident benefit		
Class 1	Class 2	Class 3	Class 1	Class 2	Class 3
-.0089	-.0101	-.0102	-.00265	-.0008	-.0005
(.0003)	(.0004)	(.0009)	(.0002)	(.0003)	(.0006)
Collision					
$\Delta D = (2003-2001)-(1999-1997)$			$\Delta D = (1996-1994)-(1993-1991)$		
-.0092	-.0126	-.0126	-.0114	-.0127	-.0164
(.0004)	(.0005)	(.001)	(.0004)	(.0005)	(.0011)

Standard error in bracket.

Table 3: Counterfactual change in claim frequency

Actual claim frequency for 2003					
Third party Liability			Accident benefit		
Class 1	Class 2	Class 3	Class 1	Class 2	Class 3
..0353	.042	.0443	.0140	.0205	.0170
Counterfactual frequency if spread were as in 2001-03					
..0442	.0521	.0546	.0166	.0212	.0176
(25%)	(24%)	(23%)	(19 %)	(4%)	(3%)
Collision					
Actual for 2003			Actual for 1996		
..0343	.0378	.0403	.0403	.0447	.0453
Counterfactual claim frequency					
..0435	.0504	.0529	.0517	.0561	.0617
(27%)	(33%)	(31%)	(28%)	(28%)	(36%)

Percent change in bracket.

Appendix B

Proof of Lemma 1. Given individuals' equilibrium strategy $(e^*, A^*; 0, 0)$, the insurance companies' best response is to choose P, P_n, P_c such that (3) and (4) are satisfied.

The definition of m_n, m_c implies

$$\begin{aligned} m_c &= \frac{\alpha\pi_h(e_1^*)\bar{F}(A_1^*)}{\alpha\pi_h(e_1^*)\bar{F}(A_1^*) + (1-\alpha)\pi_l(e_1^*)\bar{F}(A_1^*)} \\ &= \frac{\alpha\pi_h(e_1^*)}{\alpha\pi_h(e_1^*) + (1-\alpha)\pi_l(e_1^*)}, \end{aligned}$$

$$m_n = \frac{[\alpha - \alpha\pi_h(e_1^*)] + \alpha\pi_h(e_1^*)F(A_1^*)}{[1-\alpha\pi_h(e_1^*) - (1-\alpha)\pi_l(e_1^*)] + [\alpha\pi_h(e_1^*)F(A_1^*) + (1-\alpha)\pi_l(e_1^*)F(A_1^*)]}.$$

If we denote

$$\frac{a}{b} = \frac{[\alpha - \alpha\pi_h(e_1^*)]}{[1-\alpha\pi_h(e_1^*) - (1-\alpha)\pi_l(e_1^*)]}$$

and

$$\frac{c}{d} = \frac{\alpha\pi_h(e_1^*)}{\alpha\pi_h(e_1^*) + (1-\alpha)\pi_l(e_1^*)},$$

then

$$m_c = \frac{c}{d}, \qquad m_n = \frac{a + cF(A_1^*)}{b + dF(A_1^*)}.$$

Because $\pi_h(e_1^*) > \pi_l(e_1^*)$,

$$\frac{a}{b} < \alpha,\ \frac{c}{d} > \alpha \Longrightarrow \frac{c}{d} = \frac{cF(A_1^*)}{dF(A_1^*)} > \frac{a}{b}.$$

This implies

$$m_c = \frac{c}{d} > m_n = \frac{a + cF(A_1^*)}{b + dF(A_1^*)} > \frac{a}{b}.$$

Given the equilibrium belief, it is clear $P_n < P_c$. □

Proof of Claim 1. Given the definition of q_0, q_1, m_n, m_c,

$$m_c = \frac{\alpha\pi_h(e_1^*)}{\alpha\pi_h(e_1^*) + (1-\alpha)\pi_l(e_1^*)} = q_1 > \alpha$$

for any A_1^*. From the previous proof we already know that $m_n < m_c$ but

$$m_n = \frac{a + cF(A_1^*)}{b + dF(A_1^*)} > \frac{a}{b} = q_0.$$

Hence we prove the claim. □

Proof of Proposition 1. As $P_n < P_c$, we know that $M < 0$. Because $c'(0) = 0$ and $\pi_i'(0) < 0$, we conclude

$$\frac{dv_i}{de}|_{(e=0)} > 0.$$

Meanwhile,

$$\lim_{e \to 1} \frac{dv_i}{de} < 0.$$

Hence, by Intermediate value theorem, there exists an $e^* \in (0, 1)$ such that

$$\pi_i'(e^*)M - c'(e^*) = 0. \tag{A1}$$

□

Proof of Claim 2. We already know that in any competitive equilibrium, individuals take no care and claim for any accident in period two. Suppose there exists a competitive equilibrium in which individuals do not use a cut-off reporting rule, that is, there exists $A^1 < A^2$ such that an individual would claim if accident damage equals A^1 but would not claim if accident damage equals A^2.

Then

$$U(W - P) + U(W - P_c) \geq U(W - P - A^1) + U(W - P_n),$$

$$U(W - P) + U(W - P_c) \leq U(W - P - A^2) + U(W - P_n).$$

Combining the two inequalities gives

$$U(W - P - A^2) + U(W - P_n) \geq U(W - P - A^1) + U(W - P_n),$$

which implies that $A^1 \geq A^2$, a contradiction. Therefore, we can conclude that the only competitive equilibrium in this market is the one with a cut-off reporting rule. □

Proof of Claim 3. Given the zero-profit conditions in (3) and (4), simply differentiating P, P_n, P_c with respect to δ yields

$$\begin{aligned}\frac{dP}{d\delta} &= \frac{1}{1+r}\{\alpha\pi_h(e) + (1-\alpha)\pi_l(e)\},\\ \frac{dP_n}{d\delta} &= \frac{1}{1+r}\{m_n\pi_h(e^n) + (1-m_n)\pi_l(e^n)\},\\ \frac{dP_c(A)}{d\delta} &= \frac{1}{1+r}\{(m_c(A)\pi_h(e^c) + (1-m_c(A))\pi_l(e^c)\}.\end{aligned}$$

Thus we have proved Claim 3. □

Proof of Claim 4. At first we show that an increase in premium spread increases the cut-off point in claims. To see why this is true, note that the condition in (10) implies

$$U(W-P) - U(W-P-A^*) = U(W-P_n) - U(W-P_c).$$

Hence, as the difference ($P_c - P_n$) increases, A^* has to increase to satisfy the equality.

Next we show that an increase in premium spread increases the precaution taken to avoid accident. At first an increase in ($P_c - P_n$) results in decrease of M, which is true because the increased difference decreases $U(W-P_c) - U(W-P_n)$. The optimal condition for utility-maximization condition is

$$\pi'(e^*)M - C'(e^*) = 0.$$

At the lower level of M, e must increase to satisfy the condition. Therefore, an increase in premium spread increases effort level. □

References

ABBRING, J., P.-A. CHIAPPORI, AND J. PINQUET (2003): "Moral Hazard and Dynamic Insurance Data," *Journal of the European Economic Association*, 1, 767–820.

CARDON, J., AND I. HENDEL (2001): "Asymmetric Information in Health Insurance: Evidence from the National Medical Expenditure Survey," *Rand Journal of Economics*, 32, 408–27.

CHIAPPORI, P., AND B. SALANIÉ (2000): "Testing for Asymmetric Information in Insurance Market," *Journal of Political Economy*, 108, 56–78.

——— (2002): "Testing for Contract Theory: A Survey of Some Recent Work," Mimeo, CREST, France.

COHEN, A. (2005): "Asymmetric Information and Learning: Evidence from the Automobile Insurance Market," *The Review of Economics and Statistics*, 87, 197–207.

DAHCHOUR, M., AND G. DIONNE (2002): "Pricing of Automobile Insurance under Asymmetric Information: A Study on Panel Data," Working paper, HEC, Montreal.

DE MEZA, D., AND D. WEBB (2001): "Advantageous Selection in Insurance Markets," *Rand Journal of Economics*, 32(2), 249–62.

DIONNE, G., C. GOURIÉROUX, AND C. VANASSE (2001): "Testing for Evidence of Adverse Selection in the Automobile Insurance Markets: A Comment," *Journal of Political Economy*, 109, 444–453.

FINKELSTEIN, A., AND K. MCGARRY (2003): "Private Information and Its Effects on Market Equilibrium: New Evidence from Long-term Care Insurance," NBER working paper no. 9957.

FSCO (1996): "Bill 59 Simplified Rate and Risk Classification Filing Guidelines," Finance Services Commission of Ontario Bulletin No A-06/96, July 1996.

FSCO (2003): "Implementing Bill 198: New and Amending Regulations," Finance Services Commission of Ontario Bulletin No A-4/03, July 2003.

HOLMSTRÖM, B. (1999): "Managerial Incentives Problems: A Dynamic Perspective," *Review of Economic Studies*, 66, 169–82.

HOSIOS, A. J., AND M. PETERS (1989): "Repeated insurance contracts with adverse selection and limited commitment," *Quarterly Journal of Economics*, 104, 229–53.

LEVITT, S., AND J. PORTER (2001): "How dangerous are drinking drivers?," *Journal of Political Economy*, 109, 1198–1237.

RADNER, R. (1981): "Monitoring Agreements in a Repeated Principal-agent Relationship," *Econometrica*, 49, 1127–48.

——— (1985): "Repeated Principal-agent Games with Discounting," *Econometrica*, 53, 1173–99.

RUBINSTEIN, A., AND M. YAARI (1983): "Repeated Insurance Contracts and Moral Hazard," *Journal of Economic Theory*, 30, 79–97.