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INSURANCE AND INDIVIDUAL INCENTIVES IN ADAPTIVE CONTEXTS

By W. Kip Viscusi

Opportunities for individual learning in multi-period insurance contexts introduce fundamental economic aspects not present in conventional static models. Using a two-period model in which there are two states (accident and no accident), it is shown that more precise prior probability assessments lead to increased insurance coverage and reduced self-protection. These dynamic adverse incentive problems can be diminished by merit rating, which has a backwards influence on earlier actions. Self-protection and insurance purchases in the initial period respond in opposite fashion to changes in insurance prices in the second period, the interest rate, and parameters of the prior probability assessment.

1. Introduction

Economic analyses of insurance and its incentive effects typically focus on behavior in static contexts. In that familiar analytic terrain, the precision of individuals' probability assessments regarding the occurrence of an accident in a two-state situation is not a matter of consequence. Only the expected probability of an accident, i.e., the mean value of his prior, is of import. Economic behavior is identical whether the probabilities attached to different possible outcomes are uncertain or are known with precision.

Once the time horizon is extended beyond a single period, the shape of the prior assessment and the opportunities for information acquisition become central matters of concern. Although the subsequent analysis is quite general, the following situation is illustrative. Consider an individual facing a multi-period choice problem in which he must select the level of theft insurance coverage and self-protection (e.g., burglar alarms) in each period. He is uncertain about the probability of being robbed in each period, but he can acquire information through experience, in particular, by observing whether or not he is robbed in any period. Self-protection reduces the chance of theft and hence the chance that his insurance rates will be raised in subsequent periods, but it also reduces the opportunity for learning the true probability of robbery. In the extreme case of complete self-protection, there will be no chance of observing an adverse outcome.

The key analytic question is how uncertainty, coupled with the opportunity for learning, will affect individual incentives with respect to the purchase of insurance and self-protection. Related matters, such as the impact of merit rating on individual actions, will also be discussed. It is assumed throughout that the individual insurer assesses subjective probabilities and utilities and consciously acts to maximize his subjective expected utility.

The shape of individuals' probability assessments does matter, however, if there is the opportunity for information acquisition. For example, an individual could first purchase information regarding the probability of each state and then select his optimal insurance coverage. Even though a static model could be used to analyze this situation, the underlying behavior is essentially dynamic in nature.
In Section 2 I introduce the two-period choice problem. The principal findings of the analysis pertain to the impact of uncertainty and other exogenous elements of the choice problem on individual decisions to purchase insurance and to undertake actions that will affect the probabilities of different outcomes. These matters are the subject of Section 3. Section 4 concludes the paper.

2. OPTIMAL INSURANCE AND SELF-PROTECTION

The effect of uncertainty on individual actions will be illustrated using a simple two-period model. In each period, the individual must select his optimal insurance coverage and level of self-protection, that is, expenditures that reduce the probability of an adverse outcome. Alternatively, the analysis could be developed in terms of self-insurance—expenditures that reduce the size of the loss after an adverse outcome. I will assume that the insurance company cannot monitor the level of self-protection. It can, however, monitor the lottery outcomes and revise insurance rates in the second period accordingly. Moreover, I will assume either that individuals do not switch insurance companies in the second period or that they cannot conceal their accident record in the first period from an alternative company.

In each period, there are two possible outcomes, no accident and accident. The prior probability of no accident in the initial period is given by the Beta function $\beta(\gamma e(c), \gamma g)$, where $c$ is the level of self-protection, $\gamma$ is a parameter affecting the sharpness of the prior assessment, and $e$ and $g$ are two parameters of the Beta distribution. Increases in expenditures on self-protection have a positive and non-increasing effect on the value of $e$, that is, $e' > 0$ and $e'' \leq 0$. The expected probability of no accident in the first period is given by

$$E_{\beta}(\hat{p}|\gamma e(c), \gamma g) = \gamma e(c)/\gamma g = e(c)/g,$$

where this equation gives the expected probability $p$ of no accident given the parameters of the Beta distribution. Self-protection affects the mean of the prior assessment, but not its precision.

In order to make the problem tractable, I assume that the functional relationship $e(c)$ is known. Thus the individual's experiences alter his perceptions of the probability distribution generating accidents but do not affect his perceptions of the effect of self-protection on the parameters of his prior assessment. In a fully general model, the individual may also revise his expectations regarding the influence of $c$ on $e$, further complicating the analysis.

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3 This parameterization of the Beta distribution is different from standard conventions. The Beta density of $p$ with parameters $e$ and $g$ has the form

$$(\text{Const.}) \times p^{e-1}(1-p)^{g-e-1} dp.$$

Although priors with higher values of $\gamma$ are updated less, reference to priors with higher $\gamma$'s as being "sharper" is not a fully accurate description. For priors with low $\gamma$'s and sufficiently small $e$ and $g$ values, the density function becomes concentrated at the two tails of the distribution, an effect that one may not regard as representing a "looser" distribution.
Each trial is independent and identically distributed for any given level of self-protection $c$. After a history of $m$ favorable outcomes and $n$ accidents, the revised probability of no accident is determined using $\beta(\gamma c + m, \gamma g + m + n)$. The probability of no accident posterior to observing $(m, n)$ consequently is given by

\[ p(m, n) = E_{\beta}(p|\gamma c + m, \gamma g + m + n) = (\gamma c + m)/(\gamma g + m + n). \]

For the two-period case being considered, $m + n$ always equals 1 in period 2 and $m$ equals 1 if an adverse outcome does not occur in the initial period.

Two considerations led to my use of the Beta distribution rather than employing prior and posterior probabilities in their general form. First, use of a specific distribution facilitates the parameterization of the sharpness of individuals' prior assessment. A single parameter $\gamma$ can be utilized to illustrate that sharper priors (i.e., those associated with higher values of $\gamma$) are altered less by either favorable or unfavorable experiences in the initial period. Statement of the problem in its more general form would require the specification of such a parameter for each of the two possible posterior probabilities. Consequently, the comparative statics analysis of the simultaneous effect of uncertainty on posterior assessments after both successes and failures could not be undertaken. The second consideration that led to the use of the Beta distribution is that this procedure is not particularly restrictive. As Pratt, Raiffa, and Schlaifer [4] have emphasized, the Beta distribution is quite flexible and is ideally suited for analyses of Bernoulli-type processes such as the one under consideration.

In each period, the individual is endowed with an income level $I$. The loss from an adverse outcome is $L$. The individual can both purchase self-protection $c$ and insurance $q$, where $q$ cannot exceed $L$ and the price of insurance is $\pi$. In both periods, the individual has a utility function $U$ whose shape is independent of the state. Individuals are assumed to be risk averters, i.e., $U' > 0$ and $U'' < 0$.

The objective of each person is to select the level of self-protection and insurance in each period to maximize his discounted expected utility $W$, where $r$ is the interest rate and the discount factor $\nu$ equals $1/(1 + r)$. This additively separable objective function abstracts from opportunities for borrowing, lending, or transferring funds across periods. This simplification is justified largely on the basis of convenience since an analytically tractable actuarial constraint cannot be formulated. In at least one respect, this approach is more realistic than a known actuarial constraint since individuals generally cannot be insured against the risks posed by merit rating. The only remaining notation that is required is that subscripts $a$ and $b$ indicate the no accident and accident states, respectively; the subscripts and superscripts $s$ and $f$ represent period 2 variables conditional on a success (no accident) or failure (accident) in the first period; while subscripts 1 and 2 indicate period 1 and period 2 initial income levels and loss levels.

In particular, the fixed duration of insurance contracts prevents individuals from insuring themselves on a lifetime basis. Individuals cannot spend the discounted expected value of their resources since the probabilities used to calculate the expectation are their subjective assessments and need not be identical to the market price for insurance.
The optimization problem is solved by backwards induction. If there is no accident in the first period, the second-period choice problem is to

\[
\max_{c, q_s} V^s = \nu \left\{ \frac{\gamma e(c_s) + 1}{\gamma g + 1} U(I_2 - \pi_s q_s - c_s) + \left[ 1 - \frac{\gamma e(c_s) + 1}{\gamma g + 1} \right] U(I_2 - c_s - L_2 - \pi_s q_s + q_s) \right\}.
\]

If the individual experiences an accident in the initial period, the second-period problem is to

\[
\max_{c_f, q_f} V^f = \nu \left\{ \frac{\gamma e(c_f)}{\gamma g + 1} U(I_2 - \pi_f q_f - c_f) + \left[ 1 - \frac{\gamma e(c_f)}{\gamma g + 1} \right] U(I_2 - c_f - L_2 - \pi_f q_f + q_f) \right\}.
\]

In the initial period, the individual selects his optimal level of self-protection and insurance, given that \(V^s\) and \(V^f\) are determined in optimal fashion in the second period. The problem in the initial period is to

\[
\max_{c, q} = \frac{e(c)}{g} U(I_1 - \pi q - c) + \left[ 1 - \frac{e(c)}{g} \right] U(I_1 - \pi q - c - L_1 + q) + \frac{e(c)}{g} V^s + \left[ 1 - \frac{e(c)}{g} \right] V^f = \frac{e(c)}{g} U_a + \left[ 1 - \frac{e(c)}{g} \right] U_b + \frac{e(c)}{g} V^s + \left[ 1 - \frac{e(c)}{g} \right] V^f,
\]

where \(V^s\) and \(V^f\) correspond to the optimal values in period 2 and where \(U_a\) and \(U_b\) are defined implicitly and represent the utilities of asset positions at the end of the first period associated with the no accident and accident states, respectively.

Letting the subscripts \(c\) and \(q\) indicate partial derivatives with respect to the two choice variables and letting primes indicate derivatives of functions, the first-order conditions for an interior maximum are that

1. \(W_c = 0 = -\frac{e'}{g} U_a + \frac{e'}{g} U_a' (-1) - \frac{e'}{g} U_b + \left( 1 - \frac{e'}{g} \right) U_b' (-1) + \frac{e'}{g} (V^s - V^f) = \frac{e'}{g} (U_a - U_b) + \frac{e'}{g} (U_b' - U_a') - U_b' + \frac{e'}{g} (V^s - V^f),\)

and

2. \(W_q = 0 = -\frac{\pi e}{g} U_a' + (1 - \pi) \left( 1 - \frac{e}{g} \right) U_b'.\)
In many insurance contexts an interior maximum may not exist as, for example, an individual may choose to forego insurance altogether. These cases are excluded since they are not of great relevance to the issues being considered here.

The first of these two conditions differs from the usual requirement for an optimal level of self-protection in that the individual must consider the effect of additional self-protection on his welfare in the second period. Since insurance policies are assumed to be merit-rated (i.e., \( \pi_f > \pi > \pi_s \)), \( V^s - V^f \) is positive.\(^5\) Self-protection is made more attractive in multi-period contexts to the extent that future insurance costs are reduced by a good accident record.

If individuals face actuarially fair opportunities to purchase insurance, then equation (2) reduces to the familiar result that the marginal utility of income is equated for the two states. The analysis in this essay does not proceed on the assumption that individuals can secure actuarially fair insurance since there is no need for subjective assessments to coincide with the probabilities used by the insurance company in setting the price of insurance.\(^6\) In subsequent discussion, however, I will sometimes impose the requirement that insurance rates be actuarially fair in the initial period since that assumption facilitates the comparative statics analysis of insurance purchasing decisions.

The first-order conditions are not particularly instructive in analyzing the impact of uncertainty on individual behavior. Although \( V^s \) and \( V^f \) are, respectively, decreasing and increasing functions of \( \gamma \), the impact of uncertainty on the choice variables cannot be evaluated by inspection of equations (1) and (2). The comparative statics results in the following section will be used to analyze such influences.

3. COMPARATIVE STATICS RESULTS

3.1. Derivation of Results

In this section, I will consider the impact of changes in different parameters of the problem on the optimal level of self-protection and insurance in the first period. Analogous results for the second period are not of particular interest since that situation is analytically equivalent to a conventional single-period choice problem. Readers interested in the implications of the comparative statics results, not their derivation, can proceed directly to Section 3.2.

The eight variables of interest are the two choice variables, \( c \) and \( q \), and the six principal parameters: \( \gamma, g, \nu, \pi, \pi_s, \) and \( \pi_f \). For simplicity, differentials of all other exogenous parameters are set equal to zero. Totally differentiating equations (1)

\(^5\) This assumption is somewhat stronger than is required for any of the results of the analysis to be true. The minimal merit-rating that will produce the desired results is that \( \pi_f \geq \pi \geq \pi_s \), where at least one of the strict inequalities holds.

\(^6\) In competitive equilibrium, insurance companies break even so that the price of insurance is actuarially fair for the representative individual.
and (2) produces the results that

\[
0 = \frac{e''}{g} (U_a - U_b) - \frac{e'}{g} \frac{dg}{2} (U_a - U_b) + \frac{e'}{g} [U'_a (-q d\pi - \pi dq - dc) - U'_b (-\pi dq - q d\pi - dc + dq)] + \frac{e'}{g} (U'_b - U'_a) - \frac{e}{g} \frac{dg}{2} (U'_b - U'_a) + \frac{e}{g} [U''_b (-q d\pi - q d\pi - dc + dq) - U''_a (-q d\pi - \pi dq - dc)] - U''_b (-\pi dq - q d\pi - dc + dq) + \frac{e''}{g} \frac{dc}{s} (V^s - V^f) - \frac{e'}{g^2} \frac{dg}{2} (V^s - V^f) + \frac{e'}{g} [(V'_s - V'_f) d\gamma + (V'_s - V'_f) dg + (V'_b - V'_f) d\nu] + V'_{s, s} d\pi_s - V'_{u, r} d\pi_r],
\]

and

\[
0 = -d\pi \frac{e}{g} U'_a - \frac{\pi e'}{g} \frac{dc}{2} U'_a + \frac{\pi e}{g} \frac{dg}{2} U'_a - \frac{\pi e}{g} U''_a (-\pi dq - q d\pi - dc) - d\pi \left(1 - \frac{e}{g}\right) U'_b + (1 - \pi) \left(\frac{-e'}{g} \frac{dc}{2} + \frac{e}{g^2} \frac{dg}{2}\right) U'_b + (1 - \pi) \left(1 - \frac{e}{g}\right) U''_b (-\pi dq - q d\pi - dc + dq).
\]

These conditions can be rewritten in the simpler matrix form

\[
\begin{bmatrix}
A_{11} & A_{12} \\
A_{21} & A_{22}
\end{bmatrix}
\begin{bmatrix}
dc \\
dq
\end{bmatrix}
= \begin{bmatrix}
Y_1 \\
Y_2
\end{bmatrix}.
\]

The components of the A matrix are given by

\[
A_{11} = \frac{e''}{g} (U_a - U_b) + 2 \frac{e'}{g} (U'_b - U'_a) + \frac{e}{g} U''_a + \left(1 - \frac{e}{g}\right) U''_b + \frac{e''}{g} (V^s - V^f),
\]

\[
A_{12} = A_{21} = -\frac{e'}{g} \pi U'_a - \frac{e'}{g} (1 - \pi) U'_b + \frac{\pi e}{g} U''_a - \left(1 - \frac{e}{g}\right) U''_b (1 - \pi) U''_b,
\]

\[
A_{22} = \frac{\pi^2 e}{g} U''_a + (1 - \pi)^2 \left(1 - \frac{e}{g}\right) U''_b.
\]

If the second-order conditions for an interior maximum are fulfilled, \(A_{11} < 0\), \(A_{22} < 0\), and \(\Delta = A_{11} A_{22} - (A_{12})^2 > 0\). The second-order conditions impose no restrictions on the permissible signs for \(A_{12}\).
Since knowledge of $A_{12}$’s sign is essential to ascertaining the effect of shifts of the exogenous parameters on the level of insurance, it will be instructive to ascertain whether its direction can be determined under reasonably general conditions. The signs of $Y_1$ and $Y_2$ will be examined after the sign of $A_{12}$ is ascertained. Of the four terms comprising $A_{12}$, all are negative except the last. From equation (2), we known that

$\left(1 - \frac{e}{g}\right)(1 - \pi) = \frac{e}{g} \frac{U'_a}{U'_b}$.

Substituting this value for $(1 - e/g)(1 - \pi)$ into the expression for $A_{12}$, we have that $A_{12}$ is negative if

$-\frac{e'}{g} \pi U'_a - \frac{e'}{g} (1 - \pi) U'_b + \pi \frac{e}{g} U''_a - \pi \frac{e}{g} \frac{U'_a}{U'_b} U''_b < 0,$

or

(6) \hspace{1cm} -\frac{e'}{g} \pi U'_a - \frac{e'}{g} (1 - \pi) U'_b + \pi \frac{e}{g} \left[ \frac{U''_a - U''_b}{U'_a - U'_b} \right] < 0.

There are two principal situations in which equation (6) is satisfied. First, consider the case in which the rates for insurance in the first period are actuarially fair. In such a situation, equation (2) yields the familiar result that $U'_a = U'_b$ if insurance is purchased optimally. Since utility functions are not state-dependent and since income levels are identical in the two states, $U''_a = U''_b$. Consequently, the bracketed term in equation (6) equals zero and $A_{12}$ is necessarily negative. The assumption that individuals face actuarially fair rates in the initial period does not appear to be any more restrictive than the standard assumption of actuarially fair rates in static models of insurance decisions.\(^7\)

The second class of instances in which $A_{12}$ is unambiguously negative involves restrictions on the shape of the utility function. For any utility function $U$, the measure of absolute risk aversion is defined as $-U''/U'.$\(^8\) One can thus interpret the bracketed term in equation (6) as the measure of absolute risk aversion in state $b$ minus the measure of the absolute risk aversion in state $a$. If the individual displays constant absolute risk aversion, the bracketed term equals zero and $A_{12}$ is negative. In the case of increasing absolute risk aversion, the bracketed term is negative, as is $A_{12}$. The most realistic situation is that of decreasing absolute risk aversion, that is, the odds demanded for a bet of given size should become fairer as one’s wealth increases. The value of $A_{12}$ will be negative if absolute risk aversion does not decrease at too great a rate or, more specifically, if

(7) \hspace{1cm} \frac{U''_a}{U'_a} - \frac{U''_b}{U'_b} < \frac{\frac{e'}{g} \pi U'_a + \frac{e'}{g} (1 - \pi) U'_b}{\frac{\pi e}{g} U'_a}.

\(^7\) The comparative statics results by Ehrlich and Becker [2] deal exclusively with actuarially fair situations. See Appendix B of their article.

\(^8\) See Arrow [1] for further discussion of this measure of risk aversion.
Briefly summarizing, restrictions on either market opportunities or preferences can be imposed in order to guarantee that \( A_{12} \) is negative. In particular, \( A_{12} \) will be negative if the price of insurance in the initial period is actuarially fair or if the individual’s measure of absolute risk aversion is constant, increasing, or decreasing at not too great a rate.

The values of \( Y_1 \) and \( Y_2 \) implied by equations (3) and (4) are given by

\[
Y_1 = -d\pi \left[ \frac{e'}{g} U_a' + \frac{q e}{g} U_b' - \frac{e'}{g} q U_a'' + \frac{e}{g} q U_a'' + q U_b'' \right]
\]

\[
- d\pi \left[ \frac{e'}{g} (V_\gamma' - V_{\pi}' \gamma) \right] - d\nu \left[ \frac{e'}{g} (V_\nu' - V_{\pi}' \nu) \right]
\]

\[
- d\pi \left[ \frac{e'}{g} V_{\pi}' \right] - d\pi \left[ \frac{e'}{g} V_{\pi}' \right]
\]

\[
= dg Y_1[g] + d\pi Y_1[\pi] + d\gamma Y_1[\gamma] + d\nu Y_1[\nu]
\]

\[
+ d\pi Y_1[\pi] + d\pi Y_1[\pi]
\]

and

\[
Y_2 = -d\pi \left[ -\frac{e}{g} U_a' + \frac{\pi e}{g} q U_a'' - \left( 1 - \frac{e}{g} \right) U_b' - q(1 - \pi) \left( 1 - \frac{e}{g} \right) U_b'' \right]
\]

\[
- dg \left[ \frac{e}{g} U_a' + \left( 1 - \pi \right) \frac{e}{g} U_b' \right]
\]

\[
= d\pi Y_2[\pi] + dg Y_2[g],
\]

where the notation \( Y_i(x) \) indicates the coefficient of \( dx \) in \( Y_i \).

The signs of the various \( Y_i[x] \) terms are summarized in Table I for future reference. The discussion below focuses on individuals who are partially insured in each period. This restriction is not of great importance since the signs of these

**TABLE I**

**Signs of the \( Y_i[x] \) Terms**

<table>
<thead>
<tr>
<th>Exogenous Variable ( x )</th>
<th>Sign of ( Y_i[x] )</th>
<th>Sign of ( Y_2[x] )</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \gamma )</td>
<td>+</td>
<td>0</td>
</tr>
<tr>
<td>( \nu )</td>
<td>-</td>
<td>0</td>
</tr>
<tr>
<td>( g )</td>
<td>+</td>
<td>( \gamma )</td>
</tr>
<tr>
<td>( \pi )</td>
<td>?</td>
<td>?</td>
</tr>
<tr>
<td>( \pi )</td>
<td>+</td>
<td>0</td>
</tr>
<tr>
<td>( \pi )</td>
<td>-</td>
<td>0</td>
</tr>
</tbody>
</table>

*The 0's indicate \( Y_i[x] \) values equal to zero, while the ?'s indicate \( Y_i[x] \) values whose sign cannot be ascertained.*
terms are identical in the full insurance case. If the individual does not purchase any insurance in either of the period 2 states, the value of $Y_i[x]$ for insurance price changes (i.e., $\pi_1$ or $\pi_2$) for that state clearly equal zero since raising the price of a commodity that is not purchased will not affect individual actions.

The value of $Y_i[\gamma]$ is positive since $V^*_s < 0$ and $V^*_f > 0$, as can be readily verified. The sign of $Y_i[\nu]$ is negative since $V^*_s - V^*_f > 0$. Differentiating $V^*_s$ and $V^*_f$ with respect to $\nu$ is equivalent to dividing them by $\nu$ so that the term for the no accident state $s$ is larger.

The signs of $Y_i[g]$ and $Y_2[g]$ are positive and negative, respectively. The sign of the latter term is clearcut since the marginal utility of income is positive. All terms comprising $Y_1[g]$ are clearly positive except for the final term, whose sign is the same as $V^*_f - V^*_s$. This term also is positive if

$$V^*_f - V^*_s = \nu\{-\gamma e(\gamma)(\gamma g + 1)^{-2}U^f_a - (\gamma e)(\gamma g + 1)^{-2}U^f_b\}$$

$$- \nu\{-\gamma e + 1)(\gamma)(\gamma g + 1)^{-2}U^*_a$$

$$- (\gamma e + 1)(\gamma)(\gamma g + 1)^{-2}U^*_b\} > 0.$$

Dividing by $\nu(\gamma)(\gamma g + 1)^{-2}$, this condition becomes

$$-\gamma e(U^f_a + U^f_b) + (\gamma e + 1)(U^*_a + U^*_b) > 0.$$

Since $\gamma e + 1$ exceeds $\gamma e$ and the utility in the $s$ states exceeds that in the $f$ states, this inequality holds and $Y_i[g]$ is positive.

The signs of $Y_i[\pi]$ and $Y_2[\pi]$ both are ambiguous since each expression consists of positive and negative terms whose net direction cannot be ascertained. The signs of $Y_i[\pi_1]$ and $Y_i[\pi_2]$ are positive and negative, respectively, since an increase in the price of insurance reduces individual welfare.

The above analysis of the differing signs of the terms comprising equation (4) can be used in conjunction with Cramer’s Rule to determine the effect of changes in the value of the exogenous variables on the two choice variables. The primary matter of interest is the influence of uncertain prior assessments on individual actions. The value of

$$\frac{\partial c}{\partial \gamma} = \frac{Y_i[\gamma]A_{22} - 0 \cdot A_{12}}{\Delta} = \frac{(+)(-)}{(+)} = (-),$$

and

$$\frac{\partial q}{\partial \gamma} = \frac{A_{11} \cdot 0 - A_{21}Y_i[\gamma]}{\Delta} = \frac{(-)(+)}{(+)} = (+).$$

This and all other results for insurance $q$ require that individuals face actuarially fair rates in period 1 or that they display absolute risk aversion that is either increasing, constant, or decreasing at not too great a rate. As the precision of an individual’s prior assessments increases, he decreases the amount of self-protection and increases the amount of insurance that he purchases.
An increase in the discount factor \( \nu \) implies that
\[
\frac{\partial c}{\partial \nu} = \frac{Y_1[\nu]A_{22} - 0\cdot A_{12}}{\Delta} = \frac{(-)(-)}{(+)} = (+),
\]
and
\[
\frac{\partial q}{\partial \nu} = \frac{A_{11} \cdot 0 - A_{21} Y_1[\nu]}{\Delta} = \frac{(-)(-)}{(+)} = (-).
\]

A decrease in the worker's present orientation results in an increase in self-protection and a decrease in his insurance purchases.

Shifts in the parameter \( g \) of the individual's prior assessment increase the likelihood of an accident. The influence of such changes on individual actions is that
\[
\frac{\partial c}{\partial g} = \frac{Y_1[g]A_{22} - Y_2[g]A_{12}}{\Delta} = \frac{(+)(-)(-)(-)}{(+)} = (-),
\]
and
\[
\frac{\partial q}{\partial g} = \frac{A_{11} Y_2[g] - A_{21} Y_1[g]}{\Delta} = \frac{(-)(-)(+)}{(+)} = (+).
\]

An increase in \( g \), which simultaneously lowers the mean and increases the sharpness of the prior assessment of the probability of no accident, leads to a reduction in the amount of self-protection and an increase in the amount of insurance.

The effects of changes in the three different insurance prices are given by
\[
\frac{\partial c}{\partial \pi} = \frac{Y_1[\pi]A_{22} - Y_2[\pi]A_{12}}{\Delta} = \frac{(?)(-)(-)(-)}{(+)} = (?),
\]
\[
\frac{\partial q}{\partial \pi} = \frac{A_{11} Y_2[\pi] - A_{21} Y_1[\pi]}{\Delta} = \frac{(-)(-)(-)(?)}{(+)} = (?),
\]
\[
\frac{\partial c}{\partial \pi_s} = \frac{Y_1[\pi_s]A_{22} - 0\cdot A_{12}}{\Delta} = \frac{(+)(-)}{(+)} = (-),
\]
\[
\frac{\partial q}{\partial \pi_s} = \frac{A_{11} \cdot 0 - A_{21} Y_1[\pi_s]}{\Delta} = \frac{(-)(+)}{(+)} = (+),
\]
\[
\frac{\partial c}{\partial \pi_f} = \frac{Y_1[\pi_f]A_{22} - 0\cdot A_{12}}{\Delta} = \frac{(-)(-)}{(+)} = (+),
\]
and
\[
\frac{\partial q}{\partial \pi_f} = \frac{A_{11} \cdot 0 - A_{21} Y_1[\pi_f]}{\Delta} = \frac{(-)(-)}{(+)} = (-).
\]
3.2. Implications

Table II summarizes the comparative statics results from the previous section. The findings for self-protection impose no requirements on market opportunities or on individual preferences other than the standard assumption that individuals be risk-averse. The insurance results assume either that individuals face actuarially fair rates in the initial period or that individuals display absolute risk aversion that is increasing, constant, or decreasing at not too great a rate.

<table>
<thead>
<tr>
<th>Exogenous Variables Definitions and Symbols</th>
<th>Direction of the Impact on Choice Variables</th>
</tr>
</thead>
<tbody>
<tr>
<td>Measure of Sharpness of Prior Assessment, $\gamma$</td>
<td>-</td>
</tr>
<tr>
<td>Beta Distribution Parameter, $g$</td>
<td>-</td>
</tr>
<tr>
<td>Discount Factor, $\nu$</td>
<td>$\nu$</td>
</tr>
<tr>
<td>Insurance Price in Period 1, $\pi_1$</td>
<td>$\pi_1$</td>
</tr>
<tr>
<td>Insurance Price in Period 2 following No Accident in Period 1, $\pi_2$</td>
<td>-</td>
</tr>
<tr>
<td>Insurance Price in Period 2 following Accident in Period 1, $\pi_f$</td>
<td>$\pi_f$</td>
</tr>
</tbody>
</table>

* Findings for insurance purchases assume either that individuals face actuarially fair insurance rates in the initial period or that individuals' measure of absolute risk aversion be increasing, constant, or decreasing at not too great a rate, i.e., equation (7) must be satisfied.

Perhaps the most striking feature of the results in Table II is that all unambiguous effects of parameter changes have opposite impacts on self-protection and insurance. Changes in the merit-rating procedure, the discount factor, or the two parameters of the Beta distribution ($\gamma$ and $g$) do not lead individuals to increase or reduce both methods of dealing with the risks they are facing. Rather they alter the mix of their risk-reducing actions.

Consider the implications of increasing $\gamma$, a measure of the sharpness of an individual’s prior assessment. Great precision of prior assessments leads individuals to decrease their expenditures on self-protection and increase the amount of their insurance purchases. These results have fundamental ramifications for the economic analysis of the informational problems associated with insurance. In particular, greater precision of individuals’ prior assessments will tend to increase adverse incentives difficulties because those with sharper priors will both increase their insurance coverage and reduce their efforts to diminish the probability of an accident. The sharpness of individuals’ probability assessments consequently may exert a pivotal role on generating the type of behavior that may threaten the viability of an insurance scheme and, at the very least, encourage the use of merit rating and similar mechanisms to provide appropriate incentives for those insured.

⁹ See Arrow [1], Pauly [3], Spence and Zeckhauser [5], and Zeckhauser [6] for a discussion of adverse incentives (also called moral hazard).
An increase in the Beta distribution parameter $g$ produces impacts whose
directions are identical to those associated with changes in $\gamma$. A higher value of $g$
simultaneously tightens the probability assessment and lowers the mean prob-
ability of no accident. Thus a shift in this parameter is analogous to an increase in $\gamma$
with the additional effect that the chance of an accident has been increased.
Notwithstanding the greater mean probability of an accident, individuals with
higher $g$'s reduce their self-protection and increase their insurance purchases.
Although one might have expected individuals who were confident that they were
likely to suffer an accident to undertake some preventive measures, the opposite
result is observed.

The role of the discount factor $\nu$ in affecting optimal behavior derives from the
incentive structure of the problem. Higher values of $\nu$ imply lower values of $r$ that
are used to discount future welfare. Greater future-mindedness leads consumers
to be more responsive to the merit-rating that occurs in period 2, producing an
increase in their level of self-protection and a reduction in their insurance
purchases.

In the model being considered, the insurance company has three mechanisms
by which it can influence individual actions—$\pi, \pi_r$, and $\pi_f$. The first of these, the
price of insurance in the initial period, does not appear to be an effective tool for
altering individual behavior since the direction of its impact cannot be predicted.
The reason for the ambiguity is clear. Since $\pi$ is independent of individual actions,
it is not well-suited to avoiding problems of adverse incentives. Indeed, as is well
known, the principal effect of raising $\pi$ may simply be to lead the "good risks" to
forego insurance.

Through its backwards influence on behavior in earlier periods, merit rating can
be effective in mitigating the adverse incentive problems that may be due in part to
the precision of the insured's probability assessments. In particular, higher
insurance rates for those who have experienced accidents and lower rates for
those who have avoided them can increase the self-protection that is undertaken.
Although merit-rating of this type may serve a productive and important role, its
effectiveness is diminished by the fact that the increase in self-protection will be
accompanied by lower levels of insurance coverage. Individuals will be induced to
become safer and to impose lower expected costs on the insurer, but their
reduction in insurance coverage will also diminish their importance in the total
portfolio of risks being insured.

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10 I will not consider the effect of uncertainty on competitive equilibrium since the first-order
conditions are not particularly instructive, and the model is too unwieldy to obtain comparative
statics results, such as the effect of $\gamma$ on the optimal level of $\pi_f$. Such an analysis can be set up rather easily,
however. Set the insurance prices using the assessed probabilities of the representative individual.
Taking into account the effect of the $\pi$'s and $q$'s on $c_i$, the insurance company selects $\pi, \pi_n, \pi_f, q, q_r$, and
$q_f$ to maximize the individual's discounted expected utility subject to the actuarial constraint that the
plan break even. The only obvious conclusion is that the optimal plan should strike a balance between
risk-spreading and the appropriate incentives provided by merit rating. An early analysis of a similar
result for static models is provided by Zeckhauser [6].
4. CONCLUSION

Traditional analyses of insurance distinguish two informational difficulties faced by the insurer. First, superior individual information concerning the probability of an accident may lead to adverse selection. Second, individual control over the probability of an accident (or size of the loss) may create adverse incentives difficulties if individual actions cannot be monitored. The analysis here indicates that a third problem arises from the nature of the information possessed by the insured. In particular, greater precision of individuals' probability assessments will result in a reduction in self-protection and an increase in insurance coverage. Intuitively, this result implies that less individual uncertainty will generate adverse incentives problems in dynamic contexts. Merit rating through manipulation of the prices of insurance conditional on the insured's past experiences can be used to mitigate the difficulties arising from the precision of individuals' probability assessments.

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REFERENCES