The Kyoto Economic Review 75(1): 1–11 (June 2006)

When Effort Rimes with Advantageous Selection: A New Approach to Life Insurance Pricing

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This paper investigates the demand for and pricing of life insurance when insureds' risk aversion is correlated with their precautionary effort. We assume that the population is divided into two groups: (i) very risk-averse individuals who have a low probability of death (PoD) because of the precautionary effort they undertake and (ii) less risk-averse individuals who undertake less effort and thus have a higher PoD. After computing the pooling equilibrium price under perfect competition for a class of CRRA utility and bequest functions, we compute the level of demand for life insurance by the two groups. Under the assumption of negative correlation between risk aversion and risk exposure, lower-risk individuals still buy insurance even if the price offered is higher than the fair price corresponding to their group. This is because low risks are assumed to be more risk averse, valuing insurance so highly that they can tolerate higher than fair prices. We also present some cases when low-risk individuals purchase more than their high-risk neighbors even though they realize they are subsidizing the high risks. In such cases, the insurers gain the advantage of facing a PoD which is smaller than the rate they normally expect. This fact contradicts the so-called adverse selection hypothesis.

Keywords: advantageous selection, precautionary effort, life insurance

JEL Classification Numbers: D41, D82, G22

1. Introduction

The study of adverse selection in insurance market originates from Rothschild and Stiglitz (1976). Since their seminal paper, it was usually assumed that insurers had to face adverse selection because of the practical impossibility to separate high-risk customers from low-risk ones. Customers hide their risk levels from insurers and higher-risk individuals always try to take advantage from a favorable pricing. This conventional theory of adverse selection assumes a positive correlation between self-perceived risk and real risk and that customers know more about their riskiness than the insurers and also efficiently use their information against the insurers. Moreover, the theory assumes no relationship between the level of risk aversion and riskiness. The straightforward consequence of such assumptions is that the insurers end up with a large proportion of high-risk customers.

However, many of the empirical works from early 90s fail to accept the hypothesis of existence of adverse selection in life insurance markets. Hemenway (1990) finds that at a hospital in Texas, 41 percent of injured unhelmeted motorcyclists lacked insurance coverage while only 27 percent of injured helmeted motorcyclists had no insurance. This suggests that the people who buy insurance are more cautious than the general population.

Cawley and Philipson (1999) in an empirical examination using the U.S. Teachers Insurance and Annuity Data conclude that asymmetric information is not actually a barrier to trade in the life insurance market, as they couldn't find enough evidence on existence of adverse selection in this market. They examined the effect of indicator variables for self-perceived risk on the quantity of term insurance and couldn't find any significant correlation between them. In other words, they couldn't find any significant correlation between self-perceived risk, i.e. the individuals' beliefs about their riskiness, and the demand for term insurance. This suggests the misspecification of claims according to which demand increases with the insureds' self-perceived expected risk.

Cawley and Philipson also examined the effect of actual risk on the quantity of life insurance demand and couldn't find any significant correlation between actual risk and the demand for life insurance. Surprisingly, they found that the high-risk individuals hold a lower quantity of insurance, which means negative covariance between risk exposure and life insurance demand. They also found evidence of bulk discounts and negative relationship between price and quantity which, indicates that low-risk individuals purchase more life insurance. Otherwise, the insurance company will not be able to afford the liabilities of high-risk individuals with lower premiums. These findings contradict the classical theory of adverse selection. They concluded that this can be due to effective underwriting policy and the fact that insurers may know their costs of production better than policyholders and the insurers' perceived risk rates are more accurate than the rates perceived by customers.

McCarthy and Mitchell (2003) found that the mortality rates of UK and US males and females purchasing term- and whole-life insurance are below that of the uninsureds. For example, they found that mortality rate for male purchasers of whole-life insurance is only 77.6 and 78.6 percent of the total population mortality rate for the UK and the US, respectively.

Meza and Webb (2001) state that in addition to precautionary effort that explains the negative relationship between insurance demand and risk level, heterogeneous optimism also supports this negative correlation: High risks are more optimistic about the events to be improbable, so they purchase less insurance.

Siegelman (2004) claims that the informational asymmetries are in the favor of insurers, not insureds as insurers utilize various strategies of underwritings and risk classifications that compensate for or even overcome whatever informational advantage policyholders might have. Another possibility is that a "behavioral or psychological" factor, which is the negative correlation between customers' risk aversion and their risk exposure, benefits the insurers to gain an advantage. Higher risk aversion means a willingness to pay more to eliminate risk. In other words, a more risk-averse individual tolerates a higher premium than someone who is less risk averse. If it is assumed that the low-risk individuals are also sufficiently risk-averse, they will value insurance so highly that it will be worthwhile for them to buy it even at a price higher than their actuarial fair rates. Under such assumption, insurers do not face adverse selection especially when we assume that the more risk-averse individuals, who value insurance excessively, undertake more precautionary efforts.

In the next section we develop a model to find the demand levels for two groups of different risk levels and the optimal pooling price under perfect competition. In section 3, we examine the parameters that are crucial in switching the regime to advantageous selection. Section 4 discusses the occurrence of favorable situations for insurers when PoD is considered as a decreasing function of risk aversion. Section 5 concludes.

2. The Model

2.1. The Demand Function

The population is assumed to be divided into two groups: A group of low-risk individuals L who are assumed to be very risk averse with the probability of death p_L lower than average, and a group of high-risk individuals H who are assumed to be less risk-averse people whose probability of death p_H will be higher than average. For simplicity, we assume that each group consists of the same number of perfectly identical people (same initial wealth, income, probability of death and risk aversion for all members of each group). The lower probability of death of the more risk-averse group can be explained by a higher frequency of visits to a doctor, the absence of engagement in activities reputed life-threatening or dangerous, like smoking or driving a motorbike, and in general by taking any efforts that may contribute to improving the life expectancy of individuals. We will denote by $e_i,\ i \in \{L, H\}$ the effort made by each group, and by U_i and V_i, $i \in \{L, H\}$, the utility and bequest functions of each group. When we need an explicit expression for these two functions, we will assume that for each $i \in \{L, H\}$, U_i and V_i are identical CRRA utility functions with parameter $\alpha_i \in]0, 1[$

$$\forall i \in \{L, H\}\,,\ \forall X \in R^+, \quad U_i(X) = V_i(X) = X^{1-\alpha_i}. \tag{1}$$

Effort levels are assumed to be a characteristic of individuals and cannot be adjusted. For simplicity here we consider only two groups, but we may want to consider in a more general way that the probability of death $p = p(e)$ is a decreasing function of the effort e and that the risk aversion parameter $\alpha = \alpha(e)$ is an increasing function of the effort e.

If we sum up all constraints relative to the parameters we just introduced, we have

$$e_H < e_L,$$

$$0 < p_L < p_H < 1,$$

$$\text{and } 0 < \alpha_H < \alpha_L < 1.$$

Of course, insurance companies are assumed to be unable to sort customers between the two groups and consequently will only offer one type of contract to all. The contract may be purchased in quantities subject to constraints relative to wealth and income. Each contract unit represents a potential endowment of *$1* and is sold at a unit premium q.

We are interested in computing the demand levels$x_i(q), i \in \{L, H\}$, for the two groups of people depending on the price q of one contract unit. Each group of individuals will maximize its own expected utility, and thus will solve the following problem:

$$\underset{x_i}{Max}\ EU_i(e_i, q, W_i, Y_i) = (1 - p_i)U_i(W_i + Y_i - qx_i) + p_i V_i(W_i + x_i), \tag{2}$$

subject to the constraints

$$x_i \geq 0, \tag{3}$$

$$x_i q \leq Y_i, \tag{4}$$

$$\text{and } x_i \leq Y_i, \tag{5}$$

where W_i and Y_i, $i \in \{L, H\}$ are respectively the initial wealth and expected income of the corresponding group . Here we assume that insurance premium is charged no later than the time of death. Condition (3) represents the fact that individuals cannot sell insurance on their own life. Condition (4) states that individuals are not willing to pay more than their expected income in premiums, and condition (5) states that insurers won't allow customers to cover more than the maximum possible incurred loss. The premium q should always be smaller than 1 and thus condition (4) is always satisfied when (5) is satisfied.

Assuming CRRA utility and bequest functions (1), the first order condition for Problem (2) can be written

$$-(1 - p_i)(W_i + Y_i - qx_i)^{-\alpha_i} q + p_i(W_i + x_i)^{-\alpha_i}(1 - q) = 0, \tag{6}$$

which gives us the optimal demand as

$$x_i^*(q) = \frac{(W_i + Y_i)K_i(q) - W_i}{qK_i(q) + 1}, \tag{7}$$

where

$$K_i(q) = \left(\frac{1-p_i}{p_i}q\right)^{-\frac{1}{\alpha_i}}.$$

For now, we do not consider whether the constraints (3)-(5) are satisfied or not. We simply notice that the demand in equation (7) might be negative if $K_i(q)$ is positive (always true) and sufficiently small.

2.2. Unit Contract Premium under Perfect Competition

Insurers cannot distinguish which potential customers belong to which group, but they are assumed to have a perfect knowledge of the global characteristics of the two groups.

Insurers want to maximize their expected profit, thus they solve the following problem:

$$\max_q \quad \sum_{i=H,L} [(1-p_i)q - p_i(C+1)]x_i^*(q), \tag{8}$$

where C is the processing cost of claim per contract unit. Under perfect competition, the company with the cheapest processing cost gets the whole of the market, at a price q that is so that the other companies would make an infinitesimal loss. Here we consider that, under perfect competition, all companies in the market have similar processing costs and thus the expected profit should be 0. The optimal price q^* solves

$$\sum_{i=H,L} [(1-p_i)q^* - p_i(C+1)]x_i^*(q^*) = 0. \tag{9}$$

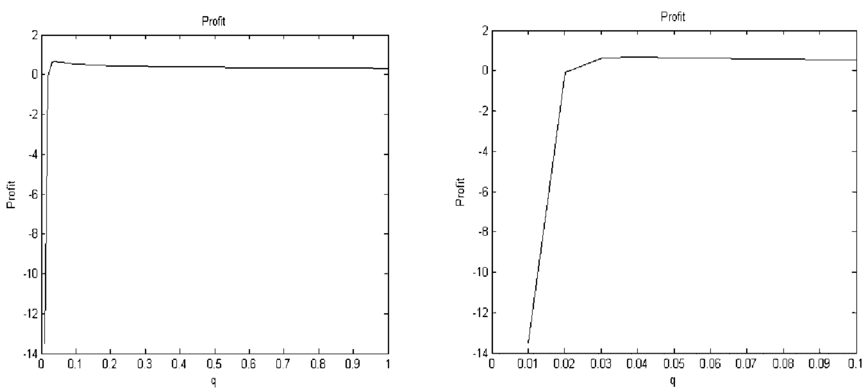

Figure 1 Profit of insurer when the parameters of two groups are as follows: $W_H = W_L = 0$, $Y_H = Y_L = 100$, $p_H = 0.02$, $\alpha_H = 0.3$, $p_L = 0.01$, $\alpha_L = 0.8$. The cost of processing $C = 0.2$ induces a pooling equilibrium price of $q^* = 0.0207$. The corresponding optimal demands are obtained as $x_L^*(q) = 40.44$ and $x_H^*(q) = 93.53$, which satisfy the conditions (3)–(5).

Inserting the optimal group demands found in (7), and after simplification, equation (9) will become

$$\begin{aligned}&[(1-p_L)q^* - p_L(C+1)][(W_L+Y_L)K_L(q^*) - W_L](q^*K_H(q^*)+1)\\&+[(1-p_H)q^* - p_H(C+1)][(W_H+Y_H)K_H(q^*) - W_H](q^*K_L(q^*)+1) = 0.\end{aligned} \tag{10}$$

This is a complex function with non-integer powers of q^*, but we can find the zeros numerically. See Figure 1 for an example of solving equation (10) graphically.

3. What Parameters Are Crucial to Determine whether There Is Advantageous Selection?

3.1. Evolution of Price and Demands when Processing Cost Is Considered as an Endogenous Factor

Here the expression "endogenous factor" is used to simply mean that we will draw the evolution of price and demands as functions of the processing cost. It does not mean that the modeling assumptions are changed; processing cost is still considered as a fixed parameter that insurers and insureds cannot change at will. Every point of the curve will represent a different system. We are interested in determining whether advantageous selection may occur naturally in this setting for some parameter values or not.

To check the effect of processing cost on switching the regime from adverse selection to advantageous selection, we have plotted the optimal demand levels for both groups as well as the corresponding optimal pooling equilibrium price for 1000 units of insurance. In graph (a) of the Figure 2 parameters are equal to those used in the previous section except the processing cost which is independent variable (endogenous factor) here, changes from 0 to 1.

For each graph, all parameters are assumed to be fixed. From graph (a) to (d), the risk aversion level of low risks increases (0.8, 0.9, 0.95, and 0.98 from graph (a) to (d), respectively) while the risk aversion level of high risks decreases successively (0.3, 0.2, 0.1, and 0.05 from graph (a) to (d), respectively). Actually we increased the gap between the risk aversions to increase the sensitivity to risk of low-risk individuals compared to the more risky individuals.

All four graphs show that increasing the processing cost tends to change the regime from adverse selection to advantageous selection as the demand of low risks exceeds that of the high risks when C is sufficiently large, given other factors. This result is logical since the low-risk individuals -who are assumed to be more risk averse- can tolerate higher levels of prices, so they do not drop out of the market easily and continue purchasing the product, while their less risk-averse risky neighbors drop out of the market faster when prices increase as a result of any increase in processing costs.

As we increase the gap between CRRA of two groups from graph (a) to (d), the switch occurs in a smaller level of processing cost. Consequently, any increase in the relative risk aversion of the low-risk group also tends to create a favorable

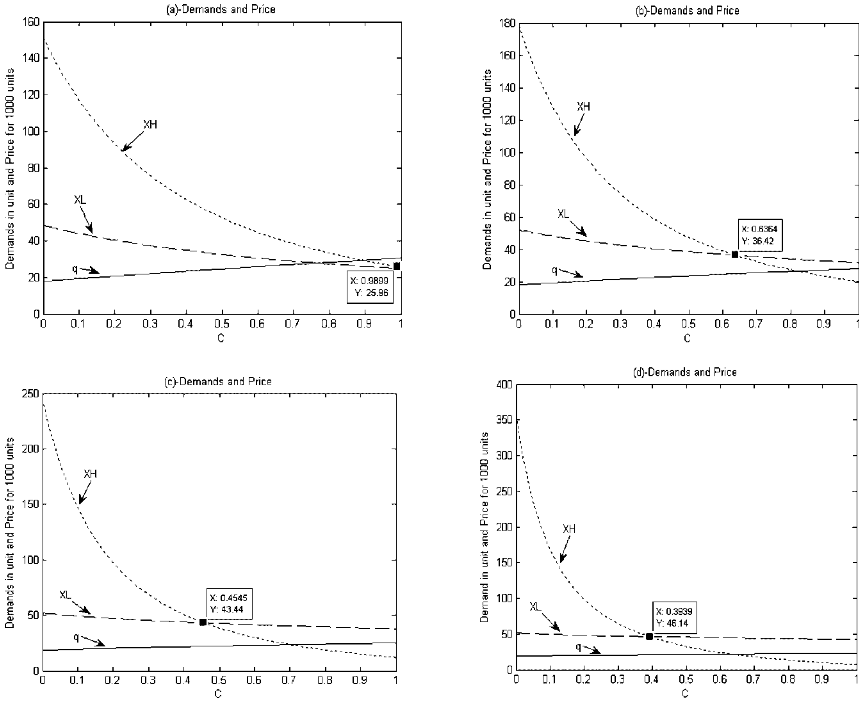

Figure 2 Demands and price when C is considered as an endogenous factor.
(a) $W_H = W_L = 0, Y_H = Y_L = 100, p_H = 0.02, \alpha_H = 0.3 p_L = 0.01, \alpha_L = 0.8$.
(b) The same as (a) except risk aversions change to: $\alpha_H = 0.2, \alpha_L = 0.9$.
(c) The same as (a) except risk aversions change to: $\alpha_H = 0.1, \alpha_L = 0.95$.
(d) The same as (a) except risk aversions change to: $\alpha_H = 0.05, \alpha_L = 0.98$.
There are two conclusions: (i) In each graph when C increases, the regime tends to change to advantageous selection. (ii) When the gap between relative risk aversions increases, the critical value of C above which the regime switches to advantageous selection decreases. Note that, here, all demand levels above 100 violate constraint (5), so the solution to the constrained problem would be different in these cases.

situation for insurers. We will discuss this fact in the next section by letting risk aversion change as an endogenous factor while other factors are kept constant.

3.2. Evolution of Price and Demands when Risk Aversion of Low Risks Is Considered as an Endogenous Factor

In this section we discuss how risk aversion affects the changing of the regime to advantageous selection. In Figure 3 we have plotted the optimal demand levels and corresponding price for 1000 units of insurance when α_L varies from 0 to 1. The parameters in graph (a) of the figure are the same as the original numerical example except that the risk aversion of low-risk group is varying from 0 to 1. Even though the demand of high-risk group exceeds that of the low risks everywhere in

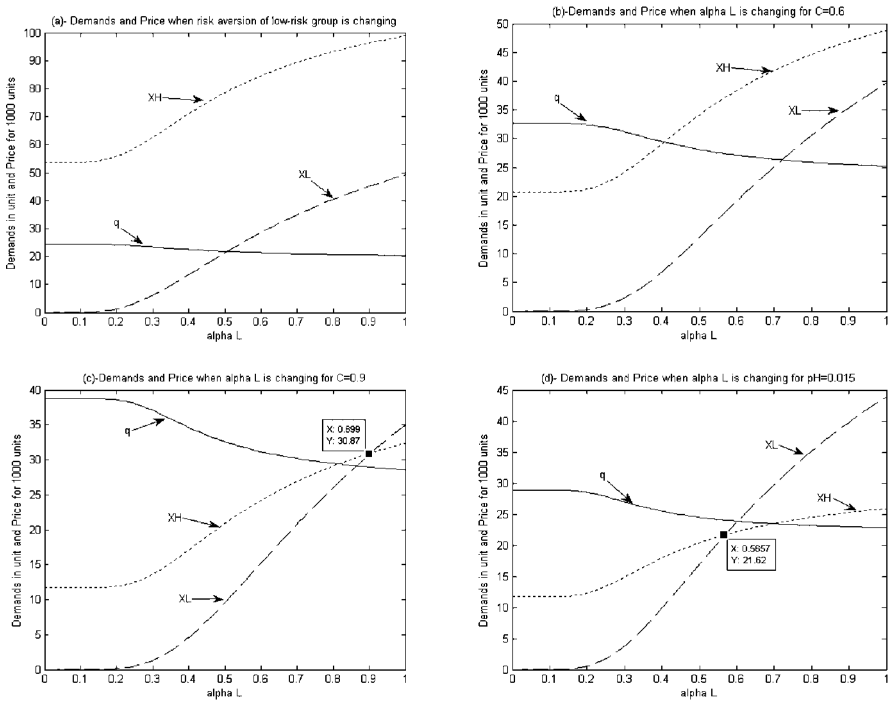

Figure 3 Demands and price when α_L is considered as an endogenous factor:
(a) $W_H = W_L = 0$, $Y_H = Y_L = 100$, $p_H = 0.02$, $\alpha_H = 0.3$, $p_L = 0.01$ and $C = 0.2$.
(b) The same as (a) except processing cost changes to 0.6.
(c) The same as (b) except processing cost increases to 0.9.
(d) The same as (c) except p_H is decreased to 0.015.
In figure (a) even though adverse selection exists for all ranges of α_L, the gap between demand levels is getting smoother when α_L increases. When C increases to 0.6 in graph (b), the gap declines further. Graph (c) shows that for $C = 0.9$, two demand curves intersect at $\alpha_L = 0.899$, indicating a switch of regime to advantageous selection. When the difference between PoDs decreases as shown in graph (d), the switch to advantageous selection regime occurs for a smaller α_L.
Figure 3 supports the idea that the increase in C has positive effect on changing the regime to advantageous selection. The figure also supports the mentioned result that when the relative risk aversion of low-risk group is increased, the regime tends to change to advantageous selection. Moreover, the decrease of PoD of high-risk group tends to have positive effect on creating a favorable situation for insurers.

the range, the gap between demands declines smoothly as we move to the right-hand side of the graph. In graph (b), we just increased the fixed amount of C from 0.2 to 0.6 and observe that this gap is getting narrower. In graph (c) we increased C from 0.6 to 0.9 exogenously. The demand functions now intersect at $\alpha_L = 0.899$ indicating the demand level of low risks exceeds that of the high-risk group from this point, creating propitious condition for insurers.

The last graph (d) is attributed to the lower level of the gap between PoDs, while other parameters are kept given as in (c). Here we observe the regime change for a lower level ofα_L. The results mentioned in the previous section are reinforced here; Figure 3 supports the idea that any increase in processing cost or the relative risk aversion of low-risk individuals tends to create a favorable situation for insurers. Moreover, Figure 3 (d) suggests that the decrease of PoD of the high-risk group tends to have a positive effect on creating this favorable situation.

4. The Selection Effect when PoD Is Considered as a Decreasing Linear Function of Risk Aversion

It is obvious that more risk-averse individuals usually exert higher level of precautionary efforts and thus have lower PoD. As a result, PoD can be assumed as a negative function of risk aversion indicating higher levels of PoDs are attributed to lower levels of risk aversion. For simplicity and logical consideration, we apply this assumption to only low risks that are more sensitive to risks. Figure 4 shows the effects of this assumption on the optimal demands and optimal price. In graph (a) of this figure, we assume the PoD of low risks p_L to be a decreasing affine function of the risk aversion α_L so that the line passes through the points (α_L, p_L) = (0.3, 0.02) and (α_L, p_L) = (0.8, 0.01). We see that the two demand curves cross at α_L = 0.3 as we expect, since risk aversions and PoDs are identical for the two groups at this point. The other intersection is at $\alpha_L = 0.109$. At these two points the optimal demands of the two groups are equal, the insurers' perceived mortality rate will be equal to the real mortality rate of the insureds and hence no information asymmetry occurs.

We can distinguish 3 cases in Figure 4 (a):

1. When $0.3 < \alpha_L < 1$, the more risky group of H demands more and therefore the so-called adverse selection regime prevails in the market.

2. When $0.109 < \alpha_L < 0.3$, even though x_L exceeds x_H, this is still a case of adverse selection since previously called "low risks" with the demand level of x_L are more risky now as their risk aversion is smaller than the risk aversion for the group which was previously called "high risks" with the demand level ofx_H.

3. The only section where advantageous selection can be observed is the extreme left where $0 < \alpha_L < 0.109$ as the currently less risky group whose demand is shown by x_H purchases more than the currently more risky group here with the demand level ofx_L. In this portion, $p_L > p_H = 0.02$ and $\alpha_L < \alpha_H = 0.3$. We see that when the processing cost is relatively small, higher PoDs together with lower risk-aversion levels lead to advantageous selection regime.

In graph (b), the processing cost C is increased from 0.2 to 0.9, and the CRRA of high risks is decreased from 0.3 to 0.1. The result of such changes is satisfactory: The market faces advantageous selection for the range $\alpha_L > 0.1$.

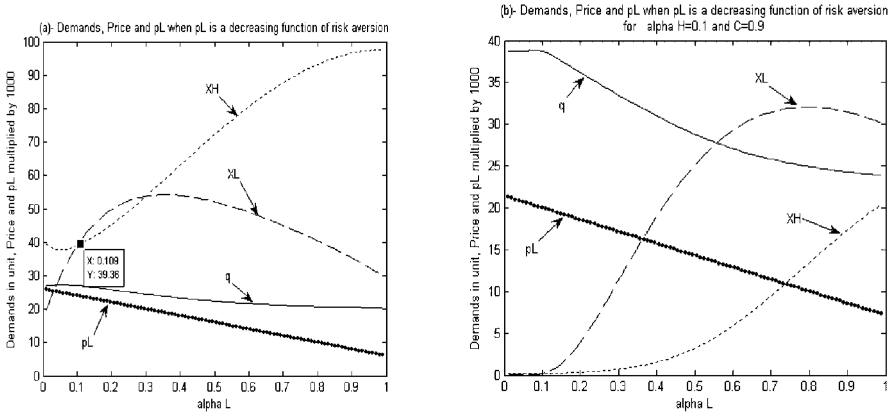

Figure 4 Demands, p_L and price when p_L is a decreasing linear function of α_L:
(a) $W_H = W_L = 0$, $Y_H = Y_L = 100$, $p_H = 0.02$, $\alpha_H = 0.3, C = 0.2$ and p_L passes through the points (0.3,0.02) and (0.8,0.01).
(b) The same as (a) except C is increased to 0.9 and α_H is decreased to 0.1. Now, p_L passes through the points (0.1, 0.02) and (0.8, 0.01). In graph (a), the insurer faces advantageous selection only in the leftmost portion where $0 < \alpha_L < 0.109$.
In graph (b), the insurer faces advantageous selection for the wide range of $\alpha_L > 0.1$. The increase in processing cost C and the relative risk aversion of low-risk individuals create a favorable situation for insurer.

5. Conclusions

The conventional theory of insurance demand under asymmetric information ignores the effect of negative correlation between risk aversion and risk exposure and also the effect of precautionary efforts on the probability of loss. The alternative advantageous selection theory assumes a negative correlation between risk aversion and risk exposure and indicates that more risk-averse individuals not only undertake more precautionary efforts to avoid loss but also are more inclined to insure. The implication of this alternative theory is that the insurers end up with relatively good-risk individuals and the market offers sufficient provision of insurance.

We could graphically present some cases when good risks are better off with pooling equilibrium rather than dropping out of the insurance pool. Since negative correlation between risk aversion and risk exposure makes the market plausible for good risks, they prefer to continue purchasing life insurance policy even though the price is not fair to them and they are actually subsidizing the high-risk policyholders.

Processing cost and risk aversion level have meaningful effect on changing the regime: For the model with processing cost as endogenous factor, when the gap between CRRA of two groups is increased, the critical value of processing cost that changes the regime to advantageous selection, decreases. Moreover, for the model with risk aversion level of low risks as endogenous factor, when the processing cost increases, the regime changes to advantageous selection for a lower level of risk aversion for low risks. Briefly speaking, with a higher gap between risk aversions, less processing cost is required to create advantageous selection regime and vice versa.

In this model, it is predicted that increasing processing cost alters the regime from adverse selection to advantageous selection since low-risk individuals who are more risk averse, can tolerate higher deductibles and prices and keep buying insurance in the market, while less risk-averse high-risk individuals can tolerate lower levels of deductibles and prices and drop out of the market. So, the market ends up with relatively more risk-averse low-risk individuals, which means switching the regime to a situation of advantageous selection.

Acknowledgements

We would like to express our gratitude to Prof. M. Kijima for his constructive comments. We are also grateful to the participants of the financial engineering seminar at the Graduate School of Economics of Kyoto University for useful discussions. We would also like to thank an anonymous referee for careful reading and useful suggestions. The corresponding author gratefully acknowledges a fellowship from the Japan Society for the Promotion of Science. The usual disclaimer applies.

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