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Insurance Markets With Differential Information

S. Hun Seog

Abstract

This article attempts to understand the outcomes when each party of an insurance contract simultaneously has superior information. I assume that policyholders have superior information about specific risks while insurers have superior information about general risks. I find that low-general-risk policyholders purchase insurance, while high-general-risk policyholders are self-insured. Among the low-general-risk policyholders, high-specific-risk policyholders purchase full insurance, while low-specific-risk policyholders purchase partial insurance. When insurers can strategically publicize their information, efficiency is improved because high-general-risk policyholders purchase actuarially fair insurance. The market segmentation is also found based on the general-risk type and the publicizing of information.

Introduction

In standard adverse selection models, policyholders are considered to possess superior information about risks (see Dionne, Doherty, and Fombaron, 2000; Chiappori, 2000 for reviews of theories and empirical tests for adverse selection). On the other hand, it is also conceivable that insurance firms also possess superior information about some risks. This case has been investigated only recently in Villeneuve (2000, 2005). Different approaches lead to significantly different outcomes. In the standard policyholder-sided adverse selection model, high-risk policyholders are fully insured and low-risk policyholders are not fully insured. In the insurer-sided adverse selection model, high-risk policyholders can be not fully insured while low-risk policyholders are fully insured.

However, each party of an insurance contract may have superior information about some part of risks. For example, policyholders have superior information about whether or not they are smokers, but health insurers may have superior information

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about how smoking affects the health condition of a policyholder or better understanding about the results of a health examination. Policyholders have superior information about their own driving habits, while insurers may have superior information about the mechanical problems of automobile brands and accident risks of diverse areas.

These observations imply that the consideration of double-sided adverse selection may provide additional insights to the understanding of insurance markets.[1] This article attempts to understand the equilibrium outcomes when each party of an insurance contract simultaneously has superior information. I decompose the risk (probability of loss) of a policyholder into a general risk and a specific risk. I assume that policyholders have superior information about specific risks while insurers have superior information about general risks. Based on this assumption, I derive the equilibrium outcomes in competitive insurance markets where insurers try to signal their information as well as screen policyholders.

Our findings are as follows. When each risk can be either high or low, low-general-risk policyholders purchase insurance, while high-general-risk policyholders are self-insured. Among the low-general-risk policyholders, high-specific-risk policyholders purchase full insurance, while low-specific-risk policyholders purchase partial insurance. I also investigate the role of publicizing information. While a mandatory publicizing of the information of insurers opens a market for high-general-risk policyholders, it does not necessarily improve efficiency. However, when insurers can strategically publicize their information, efficiency is unambiguously improved, because high-general-risk policyholders purchase actuarially fair insurance. I find the market segmentation: low-general-risk policyholders purchase insurance from insurers that do not publicize information, while high-general-risk policyholders purchase from insurers that publicize information.

The rest of the article is composed as follows. The second section describes the model. The third section discusses and summarizes the results of one-sided adverse selection cases as benchmarks. The fourth section derives the results of a double-sided adverse selection case. The fifth section discusses the role of publicizing information in resolving adverse selection problems. The last section concludes.

THE MODEL

I consider a competitive insurance market in which (potential) policyholders face a fixed insurable loss of D. Policyholders are expected utility maximizers and insurers are risk neutral. Policyholders are homogeneous except for their risk types, T. I assume that the risk of a policyholder can be decomposed into two risks, called a general risk (T_1) and a specific risk (T_2), respectively. I will focus on the case in which insurers can only observe policyholders' general risks, while policyholders can only observe their own specific risks. As an example, policyholders have superior information about whether or not they are smokers, but health insurers may have superior

[1] A similar idea is adopted to justify the misperception of risk by policyholders in Chassagnon and Villeneuve (2005). Adverse selection problems have been studied in diverse contexts. For example, the insurance literature investigates the adverse selection problems under a random severity (Doherty and Jung, 1993; Doherty and Schlesinger, 1995; Ligon and Thistle, in press).

TABLE 1
Notations

Loss size $= D$
Policyholder's type: $T \equiv T_1T_2 = HH, HL, LH, LL$
T_1: general-risk type ($= H, L$)
T_2: specific-risk type ($= H, L$)
T_1 and T_2 are independent
q_{T1}: probability of loss attributed to the general risk for type T_1
r_{T2}: probability of loss attributed to the specific risk for type T_2
The probability of loss of type $T = p_T = q_{T1} + r_{T2}$, where $T_i = H, L$: $q_H > q_L$, $r_H > r_L$.
Policyholders observe their own T_2, not T_1
Insurers observe T_1 of each policyholder, not T_2
A competitive market is assumed
$C_i = (\alpha_i, \beta_i) =$ (premium, gross indemnity) for type i-policyholders
$V(C_i\colon j) = p_jU(W - D - \alpha_i + \beta_i) + (1 - p_j)U(W - \alpha_i)$; the expected utility of a type j-policyholder when he purchases C_i
$V(C_i) = V(C_i\colon i)$
$\pi(C_i\colon j) = \alpha_i - p_j\beta_i$
$\pi(C_i) = \pi(C_i\colon i)$

information about how smoking affects the health condition of a policyholder, or better understanding on the results of health examination. In another example, policyholders have superior information about their own driving habits, while insurers may have superior information about the mechanical problems of automobile brands and road safety.

For simplicity, I assume that each of two risks T_i can be high (H) or low (L). The risk decomposition allows to express type T as $T = T_1T_2$, so that there are four risk types: $T = HH$, HL, LH, and LL. The risk (i.e., the probability of loss) of type T is denoted by p_T. I assume that p_T is determined as the sum of two risks: $p_T = q_{T1} + r_{T2}$, where $T_i = H, L$, $q_H > q_L$, and $r_H > r_L$.

Let us denote $C_i = (\alpha_i, \beta_i) =$ (premium, gross indemnity) for the insurance contracts offered by insurers to type i-policyholders. When a type j-policyholder purchases C_i, his expected utility is expressed as $V(C_i : j) = p_jU(W - D - \alpha_i + \beta_i) + (1 - p_j)U(W - \alpha_i)$, where $U(.)$ is a von Neumann–Morgenstern utility function. The expected profit of an insurer that sells C_i to a type j-policyholder is expressed as $\pi(C_i\colon j) = \alpha_i - p_j\beta_i$. For notational simplicity, let us define $V(C_i) = V(C_i\colon i)$ and $\pi(C_i) = \pi(C_i\colon i)$. I assume that insurers announce their menus of contracts to be offered to policyholders and that policyholders can observe all menus of contracts offered by insurers. Notations are summarized in Table 1.

ONE-SIDED ADVERSE SELECTION: BENCHMARK CASES

If there is no information asymmetry, the competitive insurance market will maximize the policyholder's expected utility, given the expected profits of insurers are nonnegative. An insurer will solve the following program.

Program 1 [No adverse selection]:

$$\text{Max}_{\{C_T\}} V(C_T) = p_T U(W - D - \alpha_T + \beta_T) + (1 - p_T) U(W - \alpha_T),$$

$$\text{s.t.} \quad \pi(C_T) = \alpha_T - p_T \beta_T \geq 0.$$

It is well known from the existing literature that the equilibrium contract for type T is $C_T = (p_T\ D, D)$. Each policyholder is fully insured and the expected profit of an insurer is zero.

Now, suppose that policyholders can observe both their own T_1 and T_2, while insurers can only observe T_1 of each policyholder. This situation corresponds to the case of Rothschild and Stiglitz (1976). No pooling equilibrium is possible. In a separating equilibrium, contracts $\{C^P_{iH}, C^P_{iL}\}$ solve the following program.

Program 2 [Policyholder-sided adverse selection]:[2]

$$\text{Given} \qquad T_1 = i;$$

$$\text{Max}_{\{C_{iH}, C_{iL}\}} V(C_{iL}) = p_{iL} U(W - D - \alpha_{iL} + \beta_{iL}) + (1 - p_{iL}) U(W - \alpha_{iL}),$$

$$\text{s.t.} \quad \pi(C_{ik}) = \alpha_{ik} - p_{ik}\beta_{ik} \geq 0, \quad \text{for} \quad k = H, L,$$

$$V(C_{ik}) \geq V(C_{im} : ik) \quad \text{for} \quad k, m = H, L, \quad \text{and} \quad k \neq m.$$

The first set of constraints describes the participation of insurers. The second set of constraints describes the self-selection for policyholders regarding T_2. Equilibrium outcomes are well known from Rothschild and Stiglitz (1976). In a separating equilibrium, if it exists, the following is obtained

$$C^P_{iH} = (p_{iH} D, D), C^P_{iL} = (p_{iL} t D, t D), \quad \text{where} \quad 0 < t < 1.$$

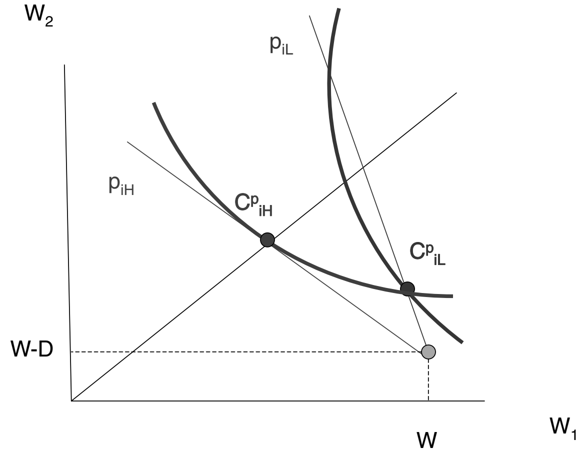
Given $T_1 = i$, high-risk policyholders are fully insured, while low-risk policyholders are partially insured. Each insurer earns zero profits. The outcome is depicted in Figure 1. Contracts are denoted by their corresponding wealth pairs in the figures throughout this article.

Now, let us consider the case in which information asymmetry is present for general risks (T_1), but not for specific risks (T_2). That is, insurers can observe both T_1 and T_2, while policyholders can only observe their own T_2. This insurer-sided adverse selection situation is studied in Villeneuve (2000, 2005) and Seog (2007) and in Maskin and Tirole (1992) in a more general principal–agent setting. Our discussion is based on Villeneuve (2005) and Seog (2007).[3] While Villeneuve (2005) find interesting outcomes

[2] In detail, the constraints are $P_{iL} U(W - D - \alpha_{iL} + \beta_{1iL}) + (1 - p_{1iL}) U(W - \alpha_{iL}) \geq p_{iL} U(W - D - \alpha_{iH} + \beta_{iH}) + (1 - p_{iL}) U(W - \alpha_{iH}) P_{iH} U(W - D - \alpha_{iH} + \beta_{iH}) + (1 - p_{iH}) U(W - \alpha_{iH}) \geq p_{iH} U(W - D - \alpha_{iL} + \beta_{iL}) + (1 - p_{iH}) U(W - \alpha_{iL})$.

[3] Unlike this article, Maskin and Tirole (1992) and Villeneuve (2000) consider a monopolistic market. Maskin and Tirole (1992) also consider a bilateral adverse selection case in a monopolistic market.

FIGURE 1
Policyholder-Sided Adverse Selection



Note: p_{ij} denotes the fair odd line for ij-policyholders; C^{p}_{ij} denotes the equilibrium contract for ij-policyholders; W_1 = wealth in the no-loss state; W_2 = wealth in the loss state.

in a market with a fixed number of insurers, the diverse outcomes make it difficult to pinpoint main implications. Seog (2007), however, shows that a unique equilibrium can be obtained in the model of Villeneuve (2005) if slight changes are made.[4] Our discussion will be focused on the unique equilibrium found in Seog.

Because insurers with superior information offer contracts, insurers can selectively offer a contract to each policyholder. This aspect is in contrast with the policyholder-sided adverse selection case in which policyholders select contracts from the set of contracts.

Now, this case can be described as a signaling game in which the contract offers by insurers are signals. I focus on the Perfect Bayesian Equilibrium (PBE) under competition (Villeneuve, 2005). Given $T_2 = i$, a PBE is: (1) a set of contracts $(C^{\bullet *}_{Hi}, C^{\bullet *}_{Li})$ where C^{j*}_{Ki} is the contract that insurer j offers to a consumer of type $T_1 = k$ and (2) a belief $\tilde{p}$ of policyholders such that: (a) actions are sequentially optimal: for any type $T_1 = k$ and any insurer j; C^{j*}_{Ki} maximizes the profit of insurer j given (i) C^{-j*}_{Ki} (the actions of the other insurers) and (ii) $\tilde{p}\,(C^{-j*}_{Ki}; \cdot)$ (its impact on beliefs given the others' actions); (b) beliefs are calculated by the Bayes rule whenever possible: $\tilde{p}(C^{\bullet *}_{Hi}) = \tilde{p}(C^{\bullet *}_{Li})$ = average probability given $T_2 = i$, if $(C^{\bullet *}_{Hi}) = (C^{\bullet *}_{Li})$; $\tilde{p}(C^{\bullet *}_{Hi}) = p_{Hi}$ and $\tilde{p}(C^{\bullet *}_{Li}) = p_{Li}$, if $(C^{\bullet *}_{Hi}) \neq (C^{\bullet *}_{Li})$; they are not restricted elsewhere.

[4] Seog (2007) makes the following changes in conditions: (i) there are a large number of insurers and (ii) in an equilibrium, contracts are required to be optimal even if some consumers are allowed to visit not all insurers announcing the same menus. In this article, condition (i) is satisfied by the assumption of the competitive market, and condition (ii) will be reflected as a refinement condition (C) in the following text. These changes lead to different results from the refinements discussed in Villeneuve (2005).

I consider only the symmetric equilibrium in which insurers offer the same menus. However, as shown in Villeneuve (2005), there are still diverse equilibria. For a concentrated analysis, I further impose the following refinement condition (C) to a PBE.

(C) A PBE is required to be optimal even if some policyholders are allowed to visit not all insurers announcing the same menus.

Condition (C) requires a PBE to be robust to the introduction of small possibilities of randomness in policyholders' visits or of positive search costs for some policyholders. This condition allows us to focus on the unique separating equilibrium as below. Please refer to the Appendix for the discussion regarding the implication of condition (C) and its relation with the uniqueness of equilibrium.[5] Now, let us consider the following program, given $T_2 = i$.

Program 3 [Insurer-sided adverse selection]:[6]

$$\mathrm{Max}_{\{C_{Hi}, C_{Li}\}} V(C_{Li}) = p_{Li} U(W - D - \alpha_{Li} + \beta_{Li}) + (1 - p_{Li}) U(W - \alpha_{Li}),$$

$$\text{s.t.} \quad \pi(C_{ki}) = \alpha_{ki} - p_{ki}\beta_{ki} \geq 0, \quad \text{for} \quad k = H, L,$$

$$\pi(C_{ki}) \geq \pi(C_{mi}\colon ki) \quad \text{for} \quad k,\ m = H,\ L, \text{ and } k \neq m,$$

$$V(C_{Hi}) \geq V(0\colon Hi).$$

The first set of constraints describes the participation of insurers. The second set of constraints describes the self-selection for insurers regarding T_1. The third set of constraints describes the participation of policyholders. In the Appendix, I present that the separating equilibrium contracts $\{C^I_{Hi}, C^I_{Li}\}$ satisfying (C) should solve program 3. Now, I obtain the following result.

Lemma 1: *[Insurer-sided adverse selection (Villeneuve, 2005; Seog, 2007)]*

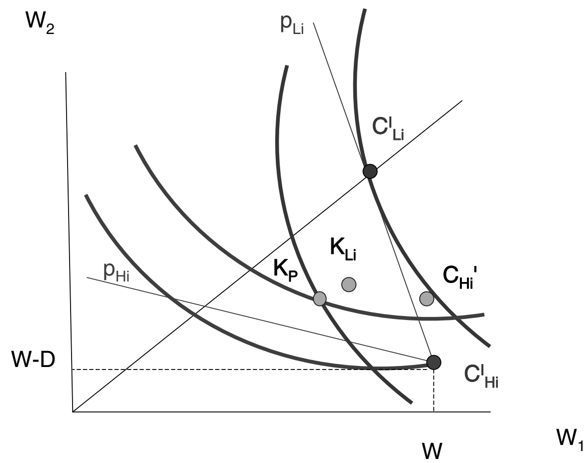
In a separating equilibrium, low-general-risk policyholders purchase actuarially fair full insurance, while high-general-risk policyholders purchase no insurance.

For the proof of this lemma, let us consider the equilibrium contracts $\{C^I_{Hi}, C^I_{Li}\}$ that are depicted in Figure 2. First, it is easy to see that $\pi(C^I_{Li}) = 0$, since the market is competitive. Let us show that, at an optimum, the self-selection constraint for insurers regarding $T_1 = L$ should be binding: $\alpha_{Li} - p_{Li}\beta_{Li} = \alpha_{Hi} - p_{Li}\beta_{Hi}$. For, if not, C_{Hi} should be located in the right side of the zero profit line containing C^I_{Li} ($\pi(C^I_{Li}) = 0$), implying that the profit from C_{Hi} would be negative. Such a contract is denoted as C'_{Hi} in Figure 2. With $\pi(C^I_{Li}) = 0$, the only nonnegative-profit contract for Hi-policyholders is no insurance: $C^I_{Hi} = (0, 0)$, and $\pi(C^I_{Hi}) = 0$. Eventually, competition induces insurers to offer full insurance to Li-policyholders: $C^I_{Li} = (p_{Li}D, D)$.

[5] See also Seog (2007) for a formal description of the condition.

[6] In detail, the constraints are $\alpha_{Hi} - p_{Hi}\beta_{Hi} \geq \alpha_{Li} - p_{Hi}\beta_{Li}$, and $\alpha_{Li} - p_{Li}\beta_{Li} \geq \alpha_{Hi} - p_{Li}\beta_{Hi}$.

FIGURE 2
Insurer-Sided Adverse Selection



Note: p_{ij} denotes the fair odd line for *ij*-policyholders; C^I_{ij} denotes the equilibrium contract for *ij*-policyholders; W_1 = wealth in the no-loss state; W_2 = wealth in the loss state.

For the completeness of proof, I need to specify the off-equilibrium beliefs to support this equilibrium. The following belief supports the equilibrium: each policyholder believes that his general-risk type is low ($T_1 = L$) if offered an off-equilibrium contract. It can be easily checked that, with this belief, the equilibrium satisfies the Intuitive Criterion of Cho and Kreps (1987).[7]

Note that no pooling equilibrium can exist. For this, suppose contrarily that there is a pooling equilibrium, say K_P in Figure 2. Now, I can find another contract that is profitable if it is sold only to *Li*-policyholders and that is preferred to the pooling contract by policyholders who believe their risks are *Li* (e.g., K_{Li} in Figure 2). Therefore, offering such a contract to *Li*-policyholders will earn positive profits, even if off-equilibrium beliefs are *Li*.[8]

DOUBLE-SIDED ADVERSE SELECTION

In this section, I synthesize models considered in the previous section. Now, I assume that insurers can only observe T_1 of policyholders, while policyholders can only

[7] The Intuitive Criterion, in our context, can be stated as follows: given an off-equilibrium contract, the beliefs of policyholders should put a zero probability to a type $T_1 = k$, if the highest possible profit of the $T_1 = k$-insurer generated by the contract is lower than the equilibrium profit. An equilibrium contract passes Intuitive Criterion if the contract is optimal given such beliefs of policyholders.

[8] A pooling equilibrium may exist in Villeneuve (2005). The difference is that I am considering a competitive market in which a large number of insurers compete, while the number of insurers does not have to be large in Villeneuve. When there are not many insurers, an insurer may not deviate even if it can take the whole market for *Li*-policyholders, since the profit from the pooling contract can be greater than the profit from the deviating contract.

observe their own T_2. Therefore, insurers need to screen policyholders' information about T_2 as well as signal information about T_1. In a separating equilibrium, contracts $\{C^*_{LL}, C^*_{LH}, C^*_{HL}, C^*_{HH}\}$ will solve the following program in equilibrium.

Program 4 [Double-sided adverse selection]:

$$\text{Max}_{\{C_{LL},C_{LH},C_{HL},C_{HH}\}} V(C_{LL}) = p_{LL}U(W - D - \alpha_{LL} + \beta_{LL}) \\ +(1 - p_{LL})U(W - \alpha_{LL}),$$

$$\text{s.t.} \quad \pi(C_{km}) \geq 0 \quad \text{for} \quad k, m = H, L,$$

$$\pi(C_{ks}) \geq \pi(C_{ms}\colon ks), \quad \text{for} \quad k, m, s = H, L, \quad \text{and} \quad m \neq k,$$

$$V(C_{ks}) \geq V(C_{km}\colon ks), \quad \text{for} \quad k, m, s = H, L, \quad \text{and} \quad m \neq k,$$

$$V(C_{km}) \geq V(0\colon km).$$

The first set of constraints describes the participation of insurers. The second set of constraints describes the self-selection for insurers regarding T_1, and the third set of constraints describes the self-selection for policyholders regarding T_2. The final set of constraints describes the participation of policyholders.

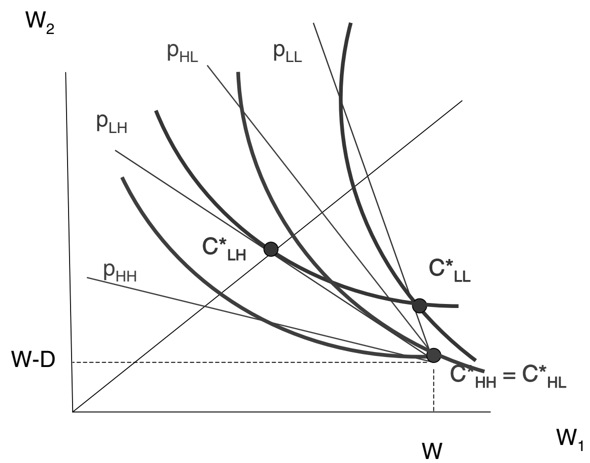
Now, let us first characterize a separating equilibrium. In a separating equilibrium, insurers offer the high-general-risk ($T_1 = H$) policyholders the menu of $\{C^*_{HH}, C^*_{HL}\}$ while they offer the low-general-risk ($T_1 = L$) policyholders the menu of $\{C^*_{LH}, C^*_{LL}\}$. First of all, note that each equilibrium contract should break even due to competition. If I consider each T_1 in isolation, the outcomes would be full insurance for T_1H and partial insurance for T_1L as in the policyholder-sided adverse selection case. Now, however, the insurer should also take into account the self-selection constraints for insurers regarding $T_1 = L$ for each T_2. Lemma 1 implies that insurers will offer no insurance to HT_2 for each T_2. Therefore, $C^*_{HH} = C^*_{HL} = 0$. Given this result, the problem reduces to the policyholder-sided adverse selection case with $T_1 = L$, leading to Rothschild and Stiglitz outcomes for LH and LL. This equilibrium is depicted in Figure 3, in which $C^*_{HH} = C^*_{HL} = 0$; $C^*_{LH} = C^P_{LH} = (p_{LH}D, D)$, $C^*_{LL} = C^P_{LL} = (p_{LL}tD, tD)$, $0 < t < 1$.

I need to specify the off-equilibrium beliefs to support this equilibrium. Similar to the insurer-sided adverse selection case, the following belief supports the equilibrium and allows it to satisfy the Intuitive Criterion: each policyholder conjectures that his general-risk type is low ($T_1 = L$) if offered an off-equilibrium contract. Finally, the nonexistence of pooling equilibrium is easily obtained, because there would be profitable contracts attracting low-specific-risk policyholders (as in Rothschild and Stiglitz, 1976), or low-general-risk policyholders (as in the discussion following Lemma 1). The results are summarized in Proposition 1.

Proposition 1: *[Double-sided adverse selection].*

In an equilibrium:

FIGURE 3
Double-Sided Adverse Selection



Note: p_{ij} denotes the fair odd line for ij-policyholders; C^*_{ij} denotes the equilibrium contract for ij-policyholders; W_1 = wealth in the no-loss state; W_2 = wealth in the loss state.

(i) Among low-general-risk policyholders, low-specific-risk policyholders purchase partial insurance while high-specific-risk policyholders purchase full insurance as in Rothschild and Stiglitz (1976). All contracts are actuarially fair.
(ii) High-general-risk policyholders purchase no insurance.

The results turn out to be a mixture of two one-sided adverse selection models. For general risks, insurers offer only to low-general-risk policyholders as in the insurer-sided adverse selection model. For specific risks with the low general risk, insurers offer contracts as in the policyholder-sided adverse selection model. However, the logic of the policy-sided adverse selection model does not apply to high-general-risk policyholders. This result is in contrast with the case of risk classification (Crocker and Snow, 1986) in which insurers offer contracts to both high- or low-categorized risks. This difference arises from the fact that general risks are the private information of the insurers in our model, while there is no private information of the insurers in the risk classification model.

Even with the screening and signaling devices that are considered as (at least partial) solutions to adverse selection problems, our results are similar to the no-device-case as in Akerlof (1970) in that only extreme markets are open. A difference is that the high-quality (low general risk) market is open in our case, while the lemons (high general risk) market is open in Akerlof.

Another interesting aspect of the results is that, unlike in one-sided adverse selection models, the relationship between insurance purchases and risk types is not in one direction. Higher risk policyholders may be more or less insured than lower risk policyholders. The highest risk (*HH*-) policyholders are not insured and the lowest risk (*LL*-) policyholders are partially insured. However, in the range of medium risks, the results depend on the relative sizes of p_{LH} and p_{HL}. If $p_{LH} \leq p_{HL}$, then high-risk (HL) policyholders are not insured, while low-risk (LH) policyholders are fully insured. On the other hand, if $p_{HL} \leq p_{LH}$ as in Figure 3, then high-risk (LH) policyholders fully insured, while low-risk (HL) policyholders are not insured. This inconsistent relationship may be a natural outcome of our complicated setting. It also points to the potential difficulty in interpreting the consistent relationship as an evidence of adverse selection. Let us summarize this result as follows.

Corollary 1: [*Double-sided adverse selection*]. The relationship between insurance purchases and risk types is not in one direction.

PUBLICIZING INFORMATION

Because insurers cannot sell insurance to high general risks when the insurer-sided adverse selection problem exists, they have strong incentives to reveal their information. Suppose that there is technology to publicize their information. I assume that the technology is not necessarily perfect, so that, when the true T_1 is k, it correctly reports R^k with probability S or incorrectly reports R^m with probability $1 - S$: $Pr.$ (report $= R^k \mid T_1 = k) = S$, $Pr.$ (report $= R^m \mid T_1 = k) = 1 - S$ for $k, m = H, L$, and $k \neq m$. I assume that $S > 1/2$.

As an example of publicizing information, a health insurer may publicize its underwriting rule based on the health examination reports observable both by the insurer and policyholders. Because policyholders can observe how insurance premium is determined based on the public information, the underwriting rule can work as a publicizing technology. Another example is that an automobile insurer publicizes its pricing rules based on policyholders' characteristics such as age and types of automobiles.[9] The publicizing technology is widely used on the Internet where price quotes are instantly provided based on the information that policyholders submit. This technology is also distinguished from the usual risk classification in that informed insurers, instead of uninformed insurers, try to reveal their information (see Crocker and Snow, 1986).[10]

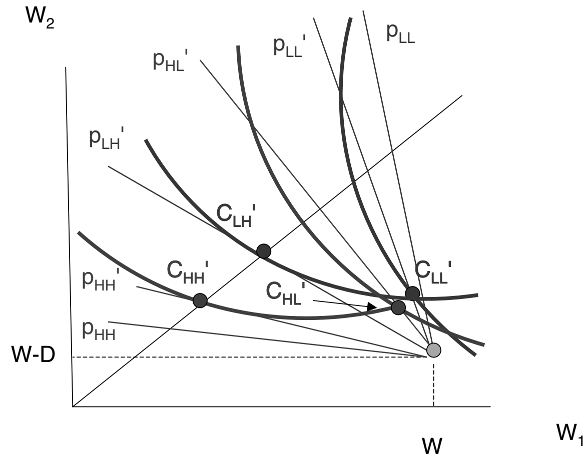
Let us first assume that all insurers are forced to publicize information and commit to follow the publicized information. Define p'_{km} as the *publicized* risk of a km'-policyholder, that is, a $T_2 = m$-policyholder who receives report R^k. I have $p'_{Hm} = \rho_H \cdot p_{Hm} + (1 - \rho_H) \cdot p_{Lm}$ and $p'_{Lm} = \rho_L \cdot p_{Lm} + (1 - \rho_L) \cdot p_{Hm}$, where $\rho_{\mathrm{H}} = \frac{Sa}{Sa+(1-S)(1-a)}$, $\rho_L = \frac{S(1-a)}{(1-S)a+S(1-a)}$, and a is the proportion of $T_1 = H$-policyholders under consideration. Based on the reports of the technology, policyholders categorize their own risks into $\{p'_{HH}, p'_{HL}, p'_{LH}, p'_{LL}\}$.[11] When $S = 1$, the technology perfectly

[9] These underwriting and pricing rules are not perfect as long as the public information does not perfectly represent the general risks of policyholders.

[10] Publicizing information can be considered hard information with noise. Another way of understanding the publicizing information is that information is transferred via a third party with noise. Publicizing information distinguishes itself from the usual direct communication devices including costly signaling and cheap talks, in that the focus here is on the interpretation of the imperfect information contents, not of the intention of the insurers.

[11] One tricky issue is that policyholders can contact many insurers to obtain good publicized information, since obtaining publicized information does not incur any costs in our model.

FIGURE 4
Mandatory Publicizing of Information



Note: p_{ij} denotes the fair odd line for *ij*-policyholders; p'_{ij} denotes the fair odd line for *ij*'-policyholders; C'_{ij} denotes the equilibrium contract for *ij*-policyholders; W_1 = wealth in the no-loss state; W_2 = wealth in the loss state.

reveals the information. Note that $p_{Hm} \geq p'_{Hm}$ and $p_{Lm} \leq p'_{Lm}$. In words, $T_1 = H$-policyholders underestimate their risks, while $T_1 = L$-policyholders overestimate their risks. Let us focus on imperfect technology, that is, $1/2 < S < 1$.

Because insurers commit to follow the technology reports, there is no need to consider the insurer-sided adverse selection problem. Therefore, equilibrium outcomes are two menus of contracts, each of which is determined similarly as in Rothschild and Stiglitz (1976). In an equilibrium, each contract should break even based on p'_{Hm} and p'_{Lm}. Equilibrium contracts are denoted by C'_{HH}, C'_{HL}, C'_{LH}, and C'_{LL} in Figure 4. HH'- and LH'-policyholders are fully insured and HL'- and LL'-policyholders are partially insured. The results are summarized in Lemma 2.

Lemma 2: *[Mandatory publicizing of information]*

Suppose that insurers are forced to publicize information and commit to follow the publicized information. I assume that the publicizing technology is not perfect.

(i) In equilibrium, HH'- and LH'-policyholders purchase full insurance, while HL'- and LL'-policyholders purchase partial insurance.
(ii) Contracts are actuarially fair based on publicized risks.

Some comments deserve to be mentioned. First, it is important to note that the commitment of insurers is critical for the results. The publicizing technology, unless $S = 1$, does not completely remove information asymmetry, because insurers still possess

To circumvent this issue, I assume that publicized information is the same for all insurers or that insurers use the common publicized information.

superior information regarding T_1. If insurers do not commit to follow the reports, they will prefer to offer no insurance to $T_1 = H$-policyholders, since C'_{HH} and C'_{HL} make losses when offered to *HH*- and *HL*-policyholders. Therefore, the above results cannot be obtained. Commitment can be obtained by sticking to publicized underwriting rules. For example, underwriting through the Internet can be used as a commitment device. Even though insurers can use more precise information, deviation from the Internet underwriting rule may cause a reputation problem in a long run.

Second, a mandatory introduction of the publicizing technology may improve or worsen the efficiency, depending on the accuracy of the publicized information. On the one hand, efficiency gains are obtained by opening a market for high-general-risk policyholders. On the other hand, low-general-risk policyholders suffer utility losses. As the publicized information becomes more accurate, I expect an efficiency improvement, because the efficiency gain from high-general-risk policyholders will become larger than the efficiency loss from the low-general-risk policyholders.

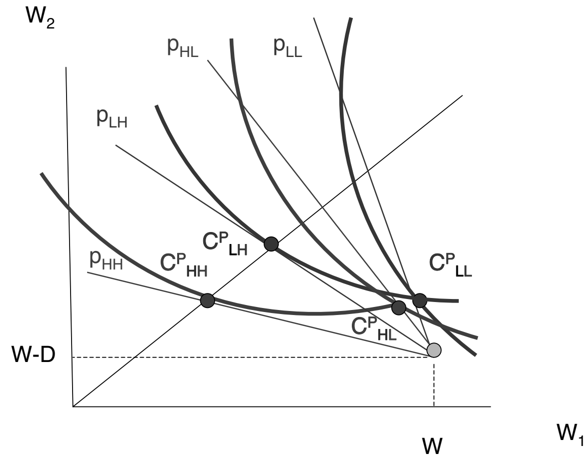
Now, let us change the assumption of mandatory publicizing of information. Instead, suppose that insurers can strategically opt to publicize information. I argue that some insurers publicize information and others do not in an equilibrium, if it exists. For, if all insurers publicize their information, then an insurer that opts not to publicize will attract all *LH*-policyholders by offering C^*_{LH}, since the policyholders prefer C^*_{LH} to C'_{LH}. On the other hand, if no insurers publicize their information, then an insurer that opts to publicize information will attract $T_1 = H$-policyholders, as *Hm*-policyholders prefer C'_{Hm} to no insurance. Therefore, in an equilibrium, if it exists, some insurers publicize information, while others do not.

Now, let us characterize equilibrium contracts. First, note that insurers that do not publicize information will offer $\{C^*_{HH} = 0, C^*_{HL} = 0\}$ and $\{C^*_{LH} = C^P{}_{LH}, C^*_{LL} = C^P{}_{LH}\}$ as in the previous section. Suppose that insurers that publicize information offer $\{C'_{HH}, C'_{HL}\}$ and $\{C'_{LH}, C'_{LL}\}$, where each contract should break even based on the publicized risks. $T_1 = H$-policyholders will purchase from insurers that publicize information, since they prefer $\{C'_{HH}, C'_{HL}\}$ to no insurance. On the other hand, $T_1 = L$-policyholders will prefer $\{C^*_{LH}, C^*_{LL}\}$ to $\{C'_{LH}, C'_{LL}\}$, since $p_{Lm} \leq p'_{Lm}$.[12] Thus, $T_1 = L$-policyholders do not purchase from insurers that publicize information. As a result, *Lm*-policyholders purchase C^*_{Lm} from insurers that do not publicize information, while *Hm*-policyholders purchase C'_{Hm} from insurers that publicize information.[13] Given

[12] In fact, there is a possibility that *LL*-policyholders prefer to purchase from insurers that publicize information even if $p_{LL} \leq p'_{LL}$, since C^*_{LL} is a partial insurance. However, I can show that this case cannot occur in an equilibrium. Suppose that *LL*-policyholders, not *LH*-policyholders, purchase from insurers that publicize information. In this case, insurers that publicize information have incentives to offer full insurance, since no *LH*-policyholders purchase from them. This full insurance, however, will also attract *LH*-policyholders. As a result, once *LL*-policyholders purchase from insurers that publicize information, *LH*-policyholders also purchase from them. However, if both policyholders purchase from the same type of insurers, then the insurers should offer separating contracts which, in turn, lead *LH*-policyholders to prefer to purchase from insurers that do not publicize information.

[13] High-general-risk policyholders are rejected (i.e., purchase no insurance) by insurers that do not publicize information, thus purchase from insurers that publicize information.

FIGURE 5
Strategic Publicizing of Information



Note: p_{ij} denotes the fair odd line for *ij*-policyholders; C_{ij}^P denotes the equilibrium contract for *ij*-policyholders; W_1 = wealth in the no-loss state; W_2 = wealth in the loss state.

this separation, $p'_{Hm} = p'_{Lm} = p_{Hm}$.[14] Thus, $C'_{HH} = C'_{LH} = C^P_{HH}$ and $C'_{HL} = C'_{LL} = C^P_{HL}$, which are depicted in Figure 5.

This result is exactly the same as if the insurer-sided adverse selection problem does not exist: $T_1 = H$-policyholders purchase from $\{C^P_{HH}, C^P_{HL}\}$ offered by insurers that publicize information while $T_1 = L$-policyholders purchase from $\{C^P_{LH}, C^P_{LL}\}$ offered by insurers that do not publicize information. Each insurer faces the policyholder-sided adverse selection case as in Rothschild and Stiglitz (1976). This result is interesting in that an *imperfect* publicizing technology leads to the same outcome as if the technology is perfect.[15] This is because the general risks of policyholders are fully separated by the technology.

Another important implication of the result is that the market segmentation is observed, implying that different general-risk types of policyholders are associated with insurers with different publicizing strategies. High-general-risk policyholders purchase from insurers with publicized and standardized underwriting rules, while low-general-risk policyholders purchase from insurers with nonpublicized or nonstandardized underwriting rules. Note that efficiency is unambiguously enhanced by allowing insurers to opt to publicize information, since $T_1 = H$-policyholders are

Low-general-risk policyholders are accepted by, and thus purchase from, insurers that do not publicize information.

14 This result is obtained by substituting a with 1 in ρ_H and ρ_L.

15 Note that this result is also due to the assumption of two types of the general risk. In the multiple-risk case as discussed below, the imperfect technology does not lead to the same result as the perfect technology.

better off and $T_1 = L$-policyholders remain the same. The results are summarized in Proposition 2.[16]

Proposition 2: *[Strategic publicizing of information].*

Suppose that insurers can strategically opt to publicize information. The following holds in an equilibrium.

(i) Given each general risk, low-specific-risk policyholders purchase partial insurance and high-specific-risk policyholders purchase full insurance as in Rothschild and Stiglitz (1976). Each contract is actuarially fair based on true risks.
(ii) [Market segmentation] High-general-risk policyholders purchase from insurers that publicize information, while low-general-risk policyholders purchase from insurers that do not publicize information.
(iii) An imperfect publicizing technology leads to the same outcome as a perfect publicizing technology.
(iv) Efficiency is improved by the strategic publicizing of information.

CONCLUSION

This article attempts to understand the outcomes when each party of an insurance contract simultaneously has superior information. I decompose the risk (probability of loss) of a policyholder into a general risk and a specific risk. I assume that policyholders have superior information about specific risks while insurers have superior information about general risks. Based on this assumption, I derive the equilibrium outcomes in competitive insurance markets where insurers try to signal their information as well as screen policyholders.

Our findings are as follows. When each risk can be either high or low, low-general-risk policyholders purchase insurance, while high-general-risk policyholders are self-insured. Among the low-general-risk policyholders, high-specific-risk policyholders purchase full insurance, while low-specific-risk policyholders purchase partial insurance. I also investigate the role of publicizing information. While a mandatory publicizing of the information of insurers opens a market for high-general-risk policyholders, it does not necessarily improve efficiency. However, when insurers can strategically publicize their information, efficiency is unambiguously improved, because high-general-risk policyholders purchase actuarially fair insurance. I find the market segmentation: low-general-risk policyholders purchase insurance from insurers that do not publicize information, while high-general-risk policyholders purchase from insurers that publicize information.

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[16] When our model is extended to a multiple-risk case, I find the following. When there is no publicizing technology, the lowest-general-risk policyholders purchase insurance, while other policyholders are self-insured. Among the lowest-general-risk policyholders, the highest-specific-risk policyholders purchase full insurance, while other policyholders purchase partial insurance. When insurers can strategically use the publicizing technology, the market segmentation still holds: the lowest-general-risk policyholders purchase insurance from insurers that do not publicize information, while other policyholders purchase from insurers that publicize information.

APPENDIX

On the Implications of Condition (C) in the Third Section

Note first that a PBE, as defined in the text and in Villeneuve (2005), requires equilibrium contracts to be optimal when consumers visit all insurers. In an equilibrium, however, when several insurers announce the same menus, a policyholder will be offered the same contracts from those insurers. Therefore, even though visiting does not incur a cost at all, it is also unnecessary for the policyholder to visit all insurers announcing the same menus. As a result, it is conceivable that some policyholders may end up with visiting only one insurer. Condition (C) requires equilibrium contracts to remain optimal even in such a case. This condition is imposed in order for an equilibrium to be robust to the introduction of small possibilities of randomness in policyholders' visits or of positive search costs for some policyholders.

Proof that the Separating Equilibrium Contracts Satisfying (C) Should Solve Program 3 in the Third Section

The market competition under the adverse selection problem leads to the low-risk policyholder's expected utility maximization, as usual in the literature. The first and third sets of constraints of program 3 guarantee the participation of insurers and high-risk policyholders. The second set of constraints is the self-selection constraints for insurers, such that insurers should not have incentives to offer wrong contracts to policyholders. Similarly to the cases of programs 1 and 2, separating equilibrium contracts will solve program 3. What I need to show is how condition (C) is reflected in the program.

For this, it is important to note that the self-selection constraints critically depend on the conjecture of the insurer regarding policyholders' behavior. The self-selection constraints of program 3 require that the profit of selling C_{ki} to ki-policyholders be higher than that of selling C_{ki} to mi-policyholders. These constraints compare profits under the insurer's conjecture that he can make a sale by offering C_{ki} to mi-policyholders. However, this conjecture does not necessarily hold in general. For example, if every policyholder visits multiple insurers, then a unilateral deviation by offering C_{ki} to mi-policyholders cannot make a sale at all. The justification for the conjecture comes from condition (C) as follows.

It suffices to show that contracts violating the self-selection constraints cannot satisfy (C). Suppose that proposed equilibrium contracts violate the self-selection constraints. Then, an insurer will have a strong incentive to deviate from offering the contracts if he expects a higher profit. Note that the equilibrium profit should be zero under competition. If an insurer offers C_{ki} to mi-policyholders, then he can earn a positive expected profit under the conjecture that some policyholders will visit once. Therefore, the proposed equilibrium contracts cannot satisfy (C).

The Uniqueness of the Equilibrium and Condition (C) in the Third Section

The uniqueness outcome also comes from (C). Without (C), the self-selection constraints in program 3 are not required as shown above. Therefore, in an equilibrium, the profit of selling C_{ki} to ki-policyholders can be lower than that of selling C_{mi} to ki-policyholders. This result may sustain as an equilibrium, if an insurer conjectures that policyholders visit all insurers. In that case, the insurer will not have an incentive to deviate from the equilibrium because a unilateral deviation cannot make any sale. That is, a could-be-profitable contract can constitute an equilibrium, as long as the insurer conjectures that he cannot make any sale from the contract. Because there are many (continuum) such contracts, multiple equilibria exist (see Villeneuve, 2005).

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