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On the Possibility of Profitable Self-Selection Contracts in Competitive Insurance Markets

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Abstract

Several studies extend the Rothschild–Stiglitz model of competitive insurance contracting with adverse selection by incorporating additional dimensions of private information and conclude that some insurers may earn positive profit in a separating, self-selection equilibrium, provided each insurer is restricted to making a single contract offer. The main result of this article is that these profitable configurations are not sustainable when individual insurers can offer multiple contracts. It is also shown that the ability to offer multiple contracts overturns equilibria that have applicants from different risk classes pooled as well as those where profits are dissipated by a fixed entry cost.

Introduction

Several studies extend the model of competitive insurance contracting introduced by Rothschild and Stiglitz (1976), in which otherwise identical insurance applicants differ with respect to their privately known loss probabilities, to incorporate additional dimensions of private information. Smart (1996) and Villeneuve (2003) assume that applicants also differ in their privately known degrees of risk aversion, while Wambach (2000) introduces heterogeneity with respect to privately known initial wealth, which gives rise to heterogeneity with respect to risk aversion. In each of these studies, there arises the possibility that the Rothschild–Stiglitz separating pair of breakeven contracts is not sustainable in the modified contracting environment. In these instances, an alternative separating outcome is identified as a sequential equilibrium, with one of the contracts earning a positive profit whereas the other contracts break even.

The critical assumption sustaining profitable self-selection contracts in each of these studies is the restriction that individual insurers can offer only a single contract. The main result established in this article is that, when this restriction is relaxed and individual insurers can offer more than one contract, there always exists a pair of incentive compatible contracts that attract some insurance applicants away from the

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proposed equilibrium offers and jointly earn positive profit. Although one of the contracts is unprofitable, the other is sufficiently profitable to subsidize these losses. As a consequence, when the proposed equilibrium for the modified Rothschild–Stiglitz environments entails positive profits for some insurers, there is no pure strategy sequential equilibrium for the two-stage representation of competitive contracting when individual insurers can make more than one contact offer in the first stage and applicants choose their preferred contract in the second.

Smart (2000), recognizing that positive profit would lead to indefinite entry by insurers, assumes that they must bear a fixed cost to enter, which dissipates the profit with finite entry. This equilibrium, too, can only be sustained when insurers are restricted to making single contract offers. When an insurer can make multiple, cross-subsidized offers, there always exists a profitable pair of defections from the equilibrium. Wambach (2000) identifies a second type of equilibrium in which applicants of different risk types are pooled. This configuration as well can never be sustained when insurers can offer cross-subsidized competing contracts.

The nature of the predicted equilibrium contracts for the modified Rothschild–Stiglitz environments is thus strongly affected by whether one assumes insurers can make multiple or only single contract offers. Furthermore, under the former hypothesis, which is the more empirically relevant of the two, no insurers earn positive profit in equilibrium.

The model of insurance contracting with an applicant pool that is heterogeneous with respect to hidden knowledge of both risk type and risk aversion is introduced in the next section. The possibility of profitable equilibrium contracts arising in this context is then examined, and the nonexistence of equilibrium is established under the assumption that individual insurers are not restricted to making single contract offers. This assumption is also shown to overturn equilibria with pooling of different risk classes and equilibria with an entry cost that dissipates profit. Possible outcomes in these instances are then discussed, and conclusions are presented in the final section.

EQUILIBRIUM WHEN RISK TYPE AND RISK AVERSION ARE HIDDEN KNOWLEDGE

Rothschild and Stiglitz (1976) posit an environment with two large classes of individuals, each of whom possesses an initial wealth W and the risk-averse von Neumann–Morgenstern utility function U, which is here assumed to be twice continuously differentiable. Each individual faces an independent risk of suffering a loss D, and individuals differ only in that those in one risk class incur the loss with a high probability p^H, while those in the other class incur the loss with a low probability $p^L < p^H$. The probability of loss is hidden knowledge. It is assumed that insurers have costless access to the information and legal instruments needed to exercise exclusivity, that the market operates under competitive conditions of free entry and exit, and that, in equilibrium, each insurer attracts either one class of individuals or a representative sample of the pool of applicants so that each contract offered earns its expected profit with probability one. If loss probabilities were common knowledge, then the market would provide all individuals with full and fair insurance.

In the first stage of the Rothschild–Stiglitz contracting game, each insurer offers a single contract that specifies a nonnegative premium and a nonnegative deductible, and in the second stage each insurance applicant selects a contract from among those offered on the market. (In case of indifference, the contract with the lower deductible is chosen.) For this two-stage screening game, a sequential equilibrium in pure strategies (hereafter, an equilibrium) is a contract for each insurer that earns a nonnegative profit and is a best response to the other agents' strategies, even off the equilibrium path, along with an optimal choice for each applicant from among the contracts offered. Hence, there must be no contract outside the equilibrium set that an insurer, having entered the market, believes would be more profitable than those in the equilibrium set.

Rothschild and Stiglitz establish that the only candidate for equilibrium is the separating pair that provides full and fair insurance to high-risk applicants and fair insurance to low risks, with high risks being indifferent between their contract and the contract chosen by low risks. Let W^H denote a fully insured wealth for high-risk types, and let (W_N^L, W_A^L) denote a partially insured, state-contingent wealth for low-risk types, with subscript A denoting the accident state in which the loss D is incurred and N denoting the no-accident state. The contracts underlying W^H and (W_N^L, W_A^L) are incentive compatible and earn maximum profit from the low risks for a given level of their expected utility only if the contracts satisfy the binding high-risk self-selection constraint

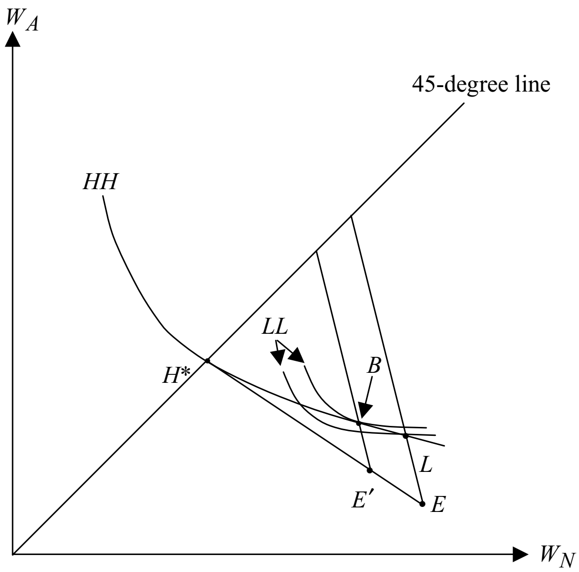
$$U(W^H) = (1 - p^H)U(W_N^L) + p^H U(W_A^L). \tag{1}$$

The Rothschild–Stiglitz contracts satisfy this constraint and break even individually. Rothschild and Stiglitz also show that these contracts cannot be sustained as an equilibrium if the proportion λ of high risks in the population of applicants is sufficiently low that both risk types prefer a profitable pooling contract over their Rothschild–Stiglitz contracts.

Smart (1996), Wambach (2000), and Villeneuve (2003) extend the Rothschild–Stiglitz model by allowing individuals to differ not only with respect to their probabilities of suffering a loss, but also with respect to their degrees of risk aversion, and by assuming that risk aversion is hidden knowledge along with risk of loss.[1] In each of these modified Rothschild–Stiglitz environments, both risk classes are composed of two types of applicants, those with high risk tolerance, represented here by utility function U, and those with low risk tolerance represented by utility function V. Each study shows that profitable equilibria can arise when the Spence–Mirrlees single-crossing property does not hold. Figure 1 illustrates this possibility. Point E represents the endowed contingent wealth $(W, W - D)$, and the line segments emanating from

[1] Villeneuve (1997) provides an earlier English language version of Villeneuve (2003). Smart (1996) and Villeneuve (2003) assume heterogeneity among insurance applicants with respect to their hidden knowledge of risk aversion. Wambach (2000) assumes that applicants possess the same von Neumann–Morgenstern utility function but are heterogeneous with respect to their hidden knowledge of endowed wealth W. As long as applicants do not exhibit constant absolute risk aversion, the hidden differences in wealth give rise to hidden differences in risk aversion.

FIGURE 1
Equilibrium With a Profitable Contract

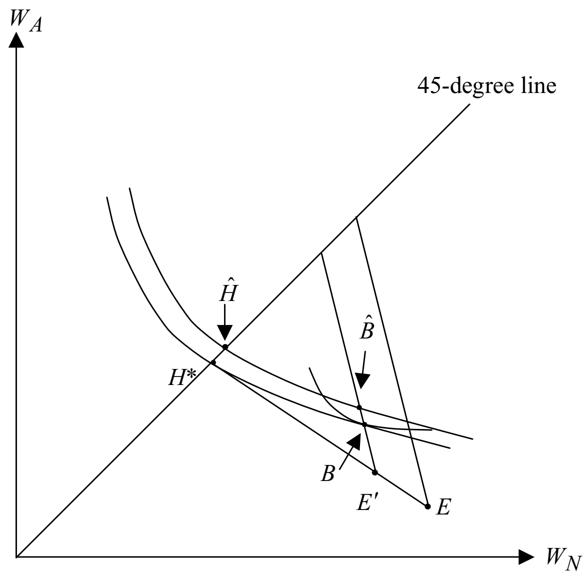


E passing through L and to H^* represent the fair-odds (zero-profit) lines for low-risk and high-risk applicants, respectively. The Rothschild–Stiglitz contracts result in point H^* for high risks and L for low risks. But these contracts are not sustainable due to the double crossing of the low-risk, low-risk tolerant (LL) type indifference curve passing through point L. Point B results from the contract most preferred by these low-risk types among those contracts that satisfy the self-selection constraint for high-risk, high-risk tolerant (HH) types associated with their Rothschild–Stiglitz contract. While the high-risk contract breaks even, the low-risk contract earns positive profit $\pi^{LL} > 0$ from each of the LL-types, and therefore, for any value of $\lambda \in (0, 1)$, the Rothschild–Stiglitz contracts cannot be sustained as an equilibrium in the two-stage screening game when the single-crossing property fails to hold.

The high-risk indifference curve labeled HH belongs to a high-risk applicant with high-risk tolerance, and the low-risk indifference curves labeled LL belong to a low-risk applicant with low-risk tolerance. In the equilibrium illustrated in Figure 1, both types of high risks receive H^*, while the LL-types receive B and the low-risk, high-risk tolerant (LH) types receive L. There is no profitable, one-contract defection from these offers under the assumption that no profitable pooling contracts exist. In this event, $\{H^*, B, L\}$ constitutes an equilibrium.

The assumption that each insurer can offer only one contract is critical to sustaining the set $\{H^*, B, L\}$ as an equilibrium. If individual insurers are free to offer more than one contract, then there do exist profitable defections from this set, and the set is therefore no longer an equilibrium. Figure 2 illustrates such a pair as $\{\hat{H}, \hat{B}\}$. The high risks are pooled at $\hat{H}$ with the fully insured wealth $\hat{W}^H$, and the underlying contract earns negative profit equal to $W^H - \hat{W}^H$ on each high-risk type, while the LL-types receive

Figure 2
A Pair of Jointly Profitable Defecting Contracts



$\hat{B}$ lying on the L-type iso-profit line from E' through B, so the underlying contract earns $\pi^{LL} > 0$ from each LL-type. For the pair to be jointly profitable, it is necessary and sufficient that

$$\lambda(W^H - \hat{W}^H) + \lambda^{LL}\pi^{LL} > 0, \tag{2}$$

where λ^{LL} is the proportion of LL-types in the applicant pool, which can be achieved by making $\hat{W}^H - W^H$ smaller than $\lambda^{LL}\pi^{LL}/\lambda$ while remaining positive.[2] This discussion establishes the following result.

Proposition: *If the only costs that insurers face are indemnity payments, then the contracts underlying $\{H^*, B, L\}$ in Figure 1 do not constitute an equilibrium for the two-stage screening game when individual insurers are free to offer a portfolio of contracts.*

The implication is that there is no equilibrium in the two-stage screening game for cases like the one illustrated in Figure 1 if individual insurers can offer more than one contract. Moreover, this result holds regardless of the distribution of the various types in the applicant pool.

It is worth noting that equilibrium with a profitable pooling contract is not possible. Standard arguments show that the high-risk, low-risk tolerant (HL) types receive full and fair insurance while the LH-types receive fair insurance with the smallest incentive compatible deductible. As discussed by Wambach (2000), if the HH- and

[2] The LL indifference curve could be kinked at point B and this argument overturning $\{H^*, B, L\}$ would still be valid.

LL-types are pooled at a contract that is incentive compatible with respect to the *HL*-types, the indifference curve of the *LL*-types cannot be steeper than that of the *HH*-types because the pooling contract would then be overturned by a profitable cream-skimming contract that attracts only the *LL*-types. On the other hand, if profitable pooling were to occur at a point of tangency, or where the *HH*-type indifference curve is steeper than the *LL*-type, then both types could be attracted to a profitable alternative that is also incentive compatible with respect to the *HL*-types. Hence, any equilibrium pooling contract must break even.

However, equilibrium with pooling cannot be sustained if insurers can offer multiple contracts. If the *HH*-type indifference curve is steeper than that of the *LL*-types, then it is easy to see that there exists a profitable pair of defecting contracts, one providing full coverage to the *HL*-types at a loss and a second, profitable and incentive compatible contract that attracts the *LL*-types away from the pool without also attracting the *HH*-types. Such a defecting pair avoids the losses associated with the *HH*-types in the pooling contract, while earning a higher profit from the *LL*-types than the pooling contract does, making it possible to subsidize the losses associated with the *HL* contract.

In the case where the indifference curves of the *HH*- and *LL*-types are tangent, it is straightforward to demonstrate the existence of a profitable defecting pair of contracts, one that provides full coverage to the *HL*-types at a loss that is more than made up by profit earned on an incentive compatible pooling contract that attracts both the *HH*- and *LL*-types. Consider an incremental defection from the proposed equilibrium contracts that increases the fully insured wealth of the *HL*-types by $dW^{HL} > 0$, while increasing the premium and reducing the deductible in the pooling contract, so that $dW_N < 0 < dW_A$. The defection is incentive compatible if[3]

$$V'_H dW^{HL} = (1 - p^H)V'_N dW_N + p^H V'_A dW_A, \tag{3}$$

and is attractive to the *LL*-types, and therefore also to the *HH*-types, if

$$(1 - p^L)V'_N dW_N + p^L V'_A dW_A > 0. \tag{4}$$

Finally, the defection is profitable if

$$\lambda^{HL} dW^{HL} + [\lambda^{HH}(1 - p^H) + \lambda^{LL}(1 - p^L)]dW_N + (\lambda^{HH} p^H + \lambda^{LL} p^L)dW_A < 0, \tag{5}$$

where λ^{HL} and λ^{HH} are the proportions of *HL*- and *HH*-types in the applicant pool, respectively.[4]

[3] In the equations that follow, primes denote derivatives and subscripts indicate the wealth argument of the utility function.

[4] To derive inequality (5), recall that the pooling contract breaks even, so the defection is profitable if profit increases. An insurance contract that results in contingent wealth (W_N, W_A) has a premium $W - W_N$ and a deductible $W_N - W_A$, and expected profit of $\pi^t = W - W_N - p^t[D - (W_N - W_A)]$ when the insured's risk of loss is p^t. Hence, an incremental change in the contract changes profit by $d\pi^t = -(1 - p^t)dW_N - p^t dW_A$. Inequality (5) is then obtained as

Equation (3) yields

$$dW_A = -\frac{1-p^H}{p^H}\frac{V_N'}{V_A'}dW_N + \frac{V_H'}{p^H V_A'}dW^{HL}, \tag{6}$$

which implies Inequality (4) given the assumed tangency of the LL and HH indifference curves. Substituting Equation (6) into Equation (5) and rearranging terms yields

$$dW^{HL} < \frac{\lambda^{HH}(1-p^L) + \lambda^{LL}(1-p^L)}{\lambda^{HL} + (\lambda^{HH}p^H + \lambda^{LL}p^L)V_H'/p^H V_A'}(-dW_N) \tag{7}$$

as a necessary and sufficient condition for the defection to be profitable. Because this inequality can easily be satisfied, pooling cannot be sustained when insurers can offer multiple, cross-subsidized contracts.

Recognizing that the positive profit to be earned by offering the contract underlying point B in Figure 1 would lead to indefinite entry by insurers, Smart (2000, p. 157) further modifies the model and assumes that firms must bear a fixed cost c to enter as "a simple way to equilibrate entry by firms."[5] Entry by insurers offering point B continues until the fixed entry cost dissipates the expected profit, resulting in m firms offering B, where m is determined by the condition

$$\lambda^{LL}\pi^{LL}/m \geq c > \lambda^{LL}\pi^{LL}/(m+1). \tag{8}$$

Once again, the assumption that each insurer is restricted to offering a single contract is critical to sustaining $\{H^*, B, L\}$ as an equilibrium. While the defecting pair $\{\hat{H}, \hat{B}\}$ identified above in establishing the Proposition is profitable, there are clearly defections that are more profitable in which the contract taken by the LL-types earns a profit that exceeds π^{LL} by an amount δ.[6] Taking account of the fixed cost of entry, the profit earned by this defection from the equilibrium is

$$\lambda(W^H - \hat{W}^H) + \lambda^{LL}(\pi^{LL} + \delta) - c \geq \lambda(W^H - \hat{W}^H) + \lambda^{LL}\delta + (m-1)c, \tag{9}$$

where the inequality follows from Condition (8). The defection can always be made profitable for any value of $m \geq 1$ by taking $\hat{W}^H - W^H$ to be positive but less than $[\lambda^{LL}\delta + (m-1)c]/\lambda$. Hence, insurers able to offer a pair contracts can profitably defect from $\{H^*, B, L\}$, which is therefore not an equilibrium.

the weighted sum of the changes in profit earned on the contract taken by the HL-types and the pooling contract taken by the HH- and LL-types.

5 Insurance premiums are adjusted to account for the fixed cost to ensure that the contracts underlying H^* and L in Figure 1 break even individually. The simplest way for Figure 1 to apply when the fixed entry cost is added to the model is to interpret point E as an individual's endowed contingent wealth net of the increase in insurance premiums needed to cover the fixed cost of entry and to assume that $\lambda = \lambda^{LL} = (1-\lambda-\lambda^{LL})$.

6 If the LL indifference curve were kinked at point B, it would have to be flatter there than the L-type iso-profit line passing through B to admit a positive value for δ.

The preceding discussion leads to the conclusion that, when individual insurers are free to offer more than one contract, the only candidate for pure strategy sequential equilibrium in the two-stage screening game is the pair of Rothschild–Stiglitz contracts providing high risks with full and fair insurance and low risks with a breakeven contract that satisfies the high-risk self-selection constraint (1). No equilibrium exists if there are pooling contracts or profitable contract portfolios such as $\{H^*, B\}$ that attract insurance applicants away from the Rothschild–Stiglitz contracts.

OUTCOMES WHEN NO TWO-STAGE EQUILIBRIUM EXISTS

As first observed by Rothschild and Stiglitz (1976, p. 643), relaxing the assumption that each insurer is restricted to offering a single contract has significant implications for the existence of an equilibrium. Indeed, the nonexistence problem they identified is aggravated when individual insurers are free to offer a portfolio of contracts because cross-subsidized pairs of contracts can overturn the Rothschild–Stiglitz contracts even when all attractive pooling contracts are unprofitable. As shown in the preceding section, relaxing the assumption that individual insurers can offer only a single contract is of yet greater consequence in the modified environments studied by Smart (1996, 2000), Wambach (2000), and Villeneuve (2003). Specifically, profitable or pooling configurations, or equilibria with profit dissipated by an entry cost, are sustainable when insurers are restricted to single contract offers, but are not sustainable when insurers can make multiple offers regardless of the distribution of the various types in the applicant pool. This is an important finding because insurers are not, in fact, restricted to making single contract offers and typically offer more than one contract.

Accepting that screening represents a plausible model for insurance contracting with hidden knowledge, the approach taken by Wilson (1977) and Hellwig (1987) offers a cogent resolution of the nonexistence problem.[7] However, their analyses assume that each insurer can offer only a single contract.[8] Were this restriction relaxed, while requiring at the third stage that each insurer must either honor all of its contract offers or exit the market, then the predicted outcome would be the one identified by Miyazaki (1977) and analyzed by Spence (1978), the cross-subsidized contracts most preferred by low risks among those that jointly break even, referred to in the literature as the Wilson–Miyazki–Spence (WMS) outcome.[9]

[7] These models were advanced to address the nonexistence problem identified by Rothschild and Stiglitz (1976). When that problem occurs, the predicted equilibrium of these models is the breakeven pooling contract most preferred by low risks. In Wilson's model, pooling is sustained by non-Nash behavior as the outcome of a two-stage game in which insurers are deterred from offering a cream-skimming contract because they anticipate exit of the pooling contract, which has been rendered unprofitable, resulting in the defection itself becoming unprofitable. Grossman (1979) also proposes a model of non-Nash behavior in which insurers may reject applicants and the pooling outcome is sustained by dissembling behavior on the part of high risks. Hellwig (1987) examines a three-stage game in which an insurer can renege on its contract offer in the third stage, and concludes that the strategically stable Nash equilibrium is the pooling outcome.

[8] Hellwig (1987) makes no explicit assumption about the number of contracts that an individual insurer can offer, but his analysis is closely tied to Wilson's (1977), which does adopt this restriction.

[9] To see this, observe that the Wilson–Hellwig pooling contract is the one most preferred by low risks among those that break even. As discussed by Wilson (1977, pp. 198-199), there

If the WMS outcome is accepted as the appropriate resolution of the nonexistence problem, then two configurations are possible in the modified environments where the risk classes are heterogeneous with respect to risk aversion, and the degree of risk aversion is also hidden knowledge. High risks are always fully insured. When high-risk tolerant types predominate among the low risks, all the low risks receive the same profitable contract that satisfies the self-selection constraint (1) for the *HH*-types and earns a profit just sufficient to offset the losses associated with the high-risk contract. When low-risk tolerant types predominate among the low risks, they are in a cross-subsidized pool with the high risks, and are indifferent to the breakeven contact taken by the *HL*-types. This configuration is illustrated in Figure 3, where *FE* represents the fair-odds line for contracts that pool high risks with *LL*-types. High risks are pooled at the unprofitable position *H*, with losses offset by profits earned off *LL*-types at point *L*, and the remaining low risks are at the breakeven position L'.[10]

Conclusions

The possibility of profitable self-selection contracts surviving as sequential equilibria in competitive insurance markets has been advanced in several studies that modify the adverse selection model of Rothschild and Stiglitz (1976) by introducing risk aversion as a second dimension of hidden knowledge. In each instance, the possibility of profitable equilibrium contracting arises when the indifference curves of the low-risk, low-risk tolerant types cross twice the indifference curves of high-risk, high-risk tolerant types, in violation of the Spence–Mirrlees single-crossing property. As a result of these "double-crossing" indifference curves, a profitable, incentive compatible contract attracts low-risk, low-risk tolerant types away from the self-selection pair of contracts identified by Rothschild and Stiglitz, and any contract with a lower premium and comparable deductible would attract all applicants and earn negative profit.

The analysis presented here shows that the critical assumption in these studies allowing the profitable contract to survive as an equilibrium of the two-stage contracting game is that each insurer is restricted to offering a single contract. When this restriction is removed, an insurer can offer a pair of contracts, and profitable cross-subsidized

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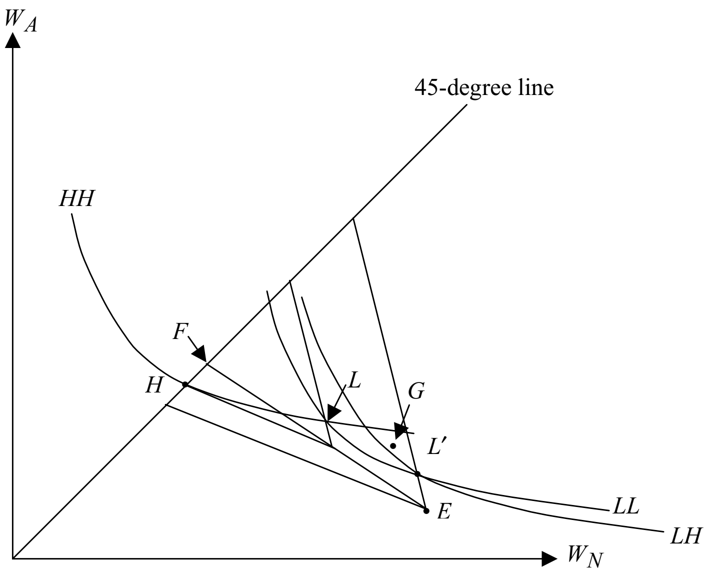
exists a profitable cross-subsidized pair of contracts preferred by both risk classes. As shown by Miyazaki (1977) and Spence (1978), the WMS outcome is the member of this class most preferred by low-risk types and thus plays the role of the Wilson–Hellwig pooling contract when each insurer can offer more than one contract and, at the third stage, must either accept or reject all of its applicants. However, if it is assumed that an insurer can reject applicants to some of its offers while accepting applicants to the remaining offers, then the WMS outcome cannot be sustained, as an insurer would reject applicants to the high-risk contract on which it expects to make a loss, leading to the Wilson–Hellwig pooling outcome. Asheim and Nilssen (1996) suggest an alternative third stage, in which each insurer can renegotiate exclusively with all its applicants, and they conclude that the unique equilibrium is the WMS outcome.

[10] Observe that Hellwig's (1987) argument applies here to show that applicants would never take the cream-skimming contract underlying point *G* in Figure 3 since an insurer offering the contract would exit in the third stage. If the insurer were not to exit, then the insurer would have to believe that the contract is profitable and that insurers offering the contract underlying *H* must believe that contract is unprofitable, so they will exit in the third stage. Given these strategies, all applicants must opt for *G*, which the insurer now believes is unprofitable, leading the insurer to exit.

FIGURE 3
Equilibrium With Cross-Subsidized Pooling



defections from the proposed equilibrium always exist, regardless of the distribution of risks and risk preferences in the applicant pool. This result shows that the predicted outcome of insurance contracting with adverse selection can be strongly influenced by assumptions, not only about the information structure but also about the contractual opportunities open to insurers. Because the more realistic assumption is that individual insurers can offer more than one contract, the more plausible outcome of competitive insurance contracting when both risk and risk aversion are hidden knowledge is an equilibrium in which no insurer earns a positive profit.

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