Adverse selection and Pareto improvements through compulsory insurance

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1. Introduction

Arrow (1963) and Akerlof (1970) have shown that competitive markets encounter difficulties when there is incomplete and asymmetrical information on product quality or riskiness. The problem of adverse selection arises in insurance markets when the purchaser of insurance has more information about the probability of a loss than the insurance company. If an insurance company is unable to distinguish a high-risk individual from a low-risk individual and each individual knows his probability of a loss, then an insurance policy giving full coverage to a low-risk individual at an actuarially fair premium will not be profitable because high-risk individuals will also purchase it. Thus the private insurance market will not provide insurance policies that offer complete coverage for low-risk individuals at an actuarially fair premium, and Akerlof (1970: 494) conjectured that compulsory health insurance may be justified on a cost-benefit basis.[1] Pauly (1974) argued that compulsory insurance may lead to a Pareto improvement if the low-risk individuals choose the level of compulsory insurance, and Johnson (1977, 1978) has claimed that compulsory insurance may result in a Pareto improvement even if high-risk individuals choose the level of compulsory insurance.

In this paper, it will be shown that the Pauly-Johnson analysis of the case for compulsory insurance is correct given their model of a competitive insurance market in which firms only engage in price competition. Recently, Rothschild and Stiglitz (1976), Wilson (1977), and Spence (1978) have analyzed the equilibrium in a competitive insurance market in which firms can limit the amount of insurance that an individual may purchase. It is shown that if there is a Nash equilibrium with price and quantity competition among firms, then compulsory insurance which does not permit voluntary supplementary insurance will not lead to a Pareto improvement. With supplementary insurance, compulsory insurance may lead to a Pareto improvement in some cases. If a Wilson equilibrium exists with cross-subsidization of insur-

* I would like to thank an anonymous referee for his comments on an earlier draft of this paper.

Public Choice 37: 547-558 (1981) 0048-5829/81/0373-0547 $01.80.

ance policies, then compulsory insurance, with or without supplementary insurance, will not be a Pareto improvement.

2. The model

There are two possible states of the world. In state 1, there is no accident, and all individuals have wealth equal to *W*. In state 2, an accident occurs which requires the expenditure of *C* dollars. Thus, in the absence of insurance, the wealth of an individual in the two states of the world is given by the point *E* in Figure 1.[2] There are two groups of individuals who are identical in all respects except that an individual in the high-risk group, which represents a constant proportion of the population, *h*, has a probability of an accident of π_H which exceeds π_L, the probability of an accident for an individual in the low-risk group. The probability of an accident for each group and the expenditure incurred as a result of the accident are exogenous variables, and thus there is no problem of moral hazard. All individuals have the same utility function,

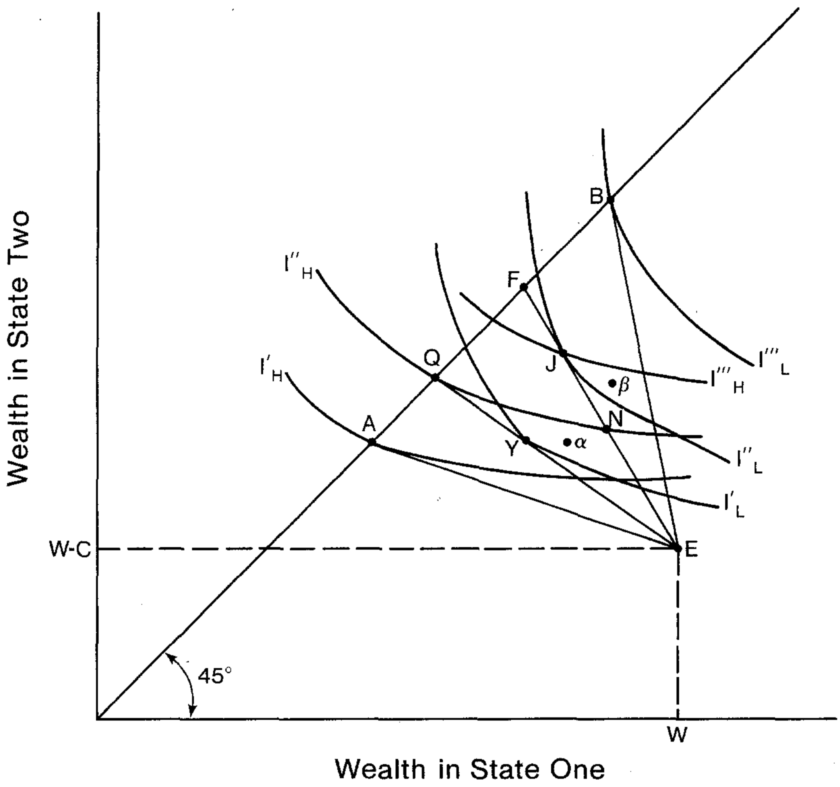

Figure 1.

$U(W)$, and are risk averse, i.e. $U'(W) > 0$, $U''(W) < 0$. Individuals maximize expected utility, and their indifference curves, which represent combinations of wealth in the two states of the world which yield constant expected utility, have slopes which are given by the following equation where Wk is wealth in state k $(k = 1, 2)$.

$$\frac{dW2}{dW1} = -\left(\frac{1-\pi_i}{\pi_i}\right)\frac{U'(W1)}{U'(W2)}; \qquad i = H, L \tag{1}$$

Note that for any given combination of wealth in the two states of the world, the slope of the indifference curve for a low-risk individual will be steeper than the slope of the indifference curve for a high-risk individual.

The insurance industry is assumed to be competitive. Let P_i be the premium in state 1 and V_i be the payout (indemnity minus premium) in state 2 of risk group i. An insurance policy represents a premium-payout combination, (P_i, V_i) which produces a wealth combination in the two states of the world as is shown below:

$$W1_i = W - P_i \tag{2}$$

$$W2_i = W - C + V_i \tag{3}$$

For simplicity, the administration costs incurred in writing insurance policies are ignored. Competition ensures that the expected profit in writing insurance policies is zero.

If firms were able to distinguish high-risk and low-risk individuals, then the insurance policies for each risk group would break-even, and the following condition would hold:

$$(1 - \pi_i)P_i = \pi_i V_i; \qquad i = H, L \tag{4}$$

Firms would offer insurance policies which would yield combinations of wealth in the two states of the world given by the lines AE and BE. These are called the fair-odds lines, and they have slopes of $-(1 - \pi_H)/\pi_H$ and $-(1 - \pi_L)/\pi_L$ respectively. (Note that an insurance policy purchased only by risk group i will have a positive (negative) expected profit if it results in a wealth combination which lies below (above) that group's fair-odds line.) As is wellknown, risk averse individuals will purchase full insurance coverage if insurance is offered on an actuarially fair basis. This is shown in Figure 1 by the tangencies of the indifference curves of high-risk and low-risk individuals, I'_H and I'''_L, at the points A and B where the wealth of an individual is independent of the state of the world. Note that if we define the price of insurance as the premium-indemnity ratio, P_i/X_i. where X_i equals $(V_i + P_i)$, then the price paid by risk group i is π_i. Thus, if insurance companies were able to identify high-risk and low-risk individuals, members of each group would purchase policies which give them full coverage at an actuarially fair premium with the price of insurance for the high-risk group exceeding the price of insurance for the low-risk group.

The problem of adverse selection arises when an insurance company is unable to distinguish high-risk and low-risk individuals, but each individual knows his probability of having an accident. Firms will not offer an insurance policy which provides full coverage for low-risk individuals at a price of π_L because high-risk individuals will also purchase this policy, and therefore it would yield a negative expected profit.

3. The Pauly-Johnson analysis

Pauly (1974: 54-60) and Johnson (1977, 1978) assumed that in a private insurance market firms will offer insurance at a given price and allow high-risk and low-risk individuals to purchase their desired levels of coverage at that price. The equilibrium price of insurance, p', would be the lowest price such that the expected receipts equaled the expected payouts. This break-even condition at a common price is given below:

$$h(1 - \pi_H)P'_H + (1 - h)(1 - \pi_L)P'_L = h\pi_H V'_H + (1 - h)\pi_L V'_L \qquad (5)$$

where

$$\frac{P'_H}{V'_H + P'_H} = \frac{P'_L}{V'_L + P'_L} = p'$$

The equilibrium envisaged by Pauly and Johnson is shown in Figure 1. High-risk individuals would purchase policies with full coverage and have the wealth combination given by the point Q. Low-risk individuals would purchase partial coverage and have a wealth combination such as at point Y. The two policies are assumed to break-even in aggregate.

Figure 1 can also be used to illustrate the arguments by Pauly and Johnson that compulsory insurance may result in a Pareto improvement.[3] Compulsory insurance implies that all individuals purchase the same policy and the premiums are set so that the policy breaks even. The average probability of an accident, $\bar{\pi}$, is equal to $(h\pi_H + (1 - h)\pi_L)$. Policies which earn zero expected profits when all individuals purchase them give rise to wealth combinations along the line FE. The slope of FE is $-(1 - \bar{\pi})/\bar{\pi}$, and it is called the market-odds line. Compulsory insurance will give rise to some wealth combination along the market-odds line which depends on the level of coverage. If low-risk individuals are in the majority and they choose the level of coverage, then compulsory insurance will lead to a Pareto improvement if low-risk individuals choose a level of coverage such as at point J which lies to the left of the point N on FE. High-risk individuals are made better off through compulsory insurance because their gain from the reduction in the price of insurance more than offsets their loss due to the reduction in coverage. On the other hand, if high-risk individuals are in the majority, they will choose compulsory full coverage insurance and the wealth combination of all individuals will be at point F. In Figure 1, this would represent a Pareto improvement because I_L' cuts the 45° line to the left of the point F. Thus, we show that the propositions of Pauly and Johnson concerning the possiblity of Pareto improvements through compulsory insurance are correct given their model of the equilibrium in competitive insurance market.[4]

The Pauly-Johnson model of equilibrium in a competitive insurance market assumes that firms engage in price competition and their analysis is relevant for insurance markets where firms cannot observe the total amount of insurance purchased by an individual. If an individual's total coverage can be monitored, then Rothschild and Stiglitz (1976: 640-642) and Wilson (1977) have argued that price and quantity competition will be a feature of competitive insurance markets. Under price and quantity competition, a firm will specify the price of insurance and the level of coverage, and this form of competition will subvert the Pauly-Johnson equilibrium. Suppose that we have the Pauly-Johnson version of equilibrium with firms offering the policies at a price p'. Then it is possible for a new firm to enter the industry and offer a new policy with a lower price and a limit on coverage which would earn a positive expected profit because it would be preferred by low-risk individuals but not by high-risk individuals. A policy such as α would give rise to a wealth combination in the region bounded by the indifference curves I_H'' and I_L' and the line BE and would entice low-risk individuals away from other firms. Their policies would be withdrawn because they would only be purchased by high-risk individuals and yield negative expected profits.

4. Equilibrium in competitive insurance markets with price and quantity competition

The existence of an equilibrium in a competitive insurance market with adverse selection is problematic as Akerlof (1970) and Rothschild and Stiglitz (1976) have shown, and the properties of the equilibrium, if it exists, depend on the assumptions which are made about a firm's expectations concerning the reactions of other firms to any new policies which it offers. First, the Nash equilibrium, which has been analyzed by Rothschild and Stiglitz (1976), will be discussed and then an alternative equilibrium concept, which has been proposed by Wilson (1977) and extended by Miyazaki (1977) and Spence (1978), will be examined.

A set of policies is a Nash equilibrium in a competitive insurance market if for each firm (a) none of its policies earns a negative expected profit and (b) there is no other set of policies that will earn a positive expected profit for that firm. The Nash concept of equilibrium assumes that the firm is myopic and does not take into account how other firms will react when it introduces a new policy. Each firm assumes that other firms will continue to offer their existing policies when it changes its menu of policies.

Rothschild and Stiglitz have shown that high-risk and low-risk individuals will purchase different policies if a Nash equilibrium exists. Thus, it can be shown, by contradiction, that there is no pooling equilibrium, i.e., an equilibrium policy which will be purchased by both risk groups. Suppose that point J in Figure 1 represents a pooling equilibrium. If all firms are offering the policy J, then a myopic firm would offer a policy such as β which would be preferred by low-risk individuals and have a positive expected profit because high-risk individuals prefer J to β. However, when β is offered, J will have a negative expected profit because it is only purchased by high-risk individuals, and therefore J will be withdrawn. When J is withdrawn, high-risk individuals will purchase β and it will now have a negative expected profit. Therefore, there is no Nash equilibrium in which both risk groups purchase the same policy.

If a Nash equilibrium exists, it will be a *separating equilibrium*, and the solution to the following problem:

$$\max_{\substack{P_i, V_i \\ i = L, H}} \quad \pi_L U(W - C + V_L) + (1 - \pi_L)U(W - P_L)$$

subject to

$$(1 - \pi_L)P_L = \pi_L V_L \tag{6}$$

$$(1 - \pi_H)P_H = \pi_H V_H \tag{7}$$

$$\pi_H U(W - C + V_H) + (1 - \pi_H)U(W - P_H) \geq \pi_H U(W - C + V_L) + (1 - \pi_H)U(W - P_L) \tag{8}$$

$$\pi_H U(W - C + V_H) + (1 - \pi_H)U(W - P_H) \geq U(W - \pi_H C) \tag{9}$$

The equilibrium premiums and payouts maximize the expected utility of a low-risk individual subject to four constraints. The first two constraints ensure that the policies for each risk group break even. The third constraint is that a high-risk individual is at least as well off purchasing the policy (P_H, V_H) as he would be if he purchased (P_L, V_L). This constraint, which is called the informational constraint, arises because of the assumption that insurance companies are unable to distinguish high-risk and low-risk individuals, and therefore, if the two groups purchase different contracts, this constraint must hold. The fourth constraint is that the expected utility of a high-risk individual must be at least as great as it would be if he purchased full coverage at the actuarially fair premium $\pi_H C$ because a high-risk individual can always admit that he is a high-risk. The solution to this problem is shown in Figure 2. The two break-even constraints imply that the solutions must lie on the fair-odds lines *AE* and *BE*. Equations (7) and (9) imply that the high-risk individuals must receive full coverage with the wealth combination at point *A*. This implies that the expected utility of the low-risk group will be maximized when the third constraint is binding, and they purchase the policy *M*.

This solution is a Nash equilibrium if the indifference curve of a low-risk individual through the point *M*, I'_L, does not intersect the market odds line. A Nash equilibrium will not exist if the market-odds line is *F′E* because there is a

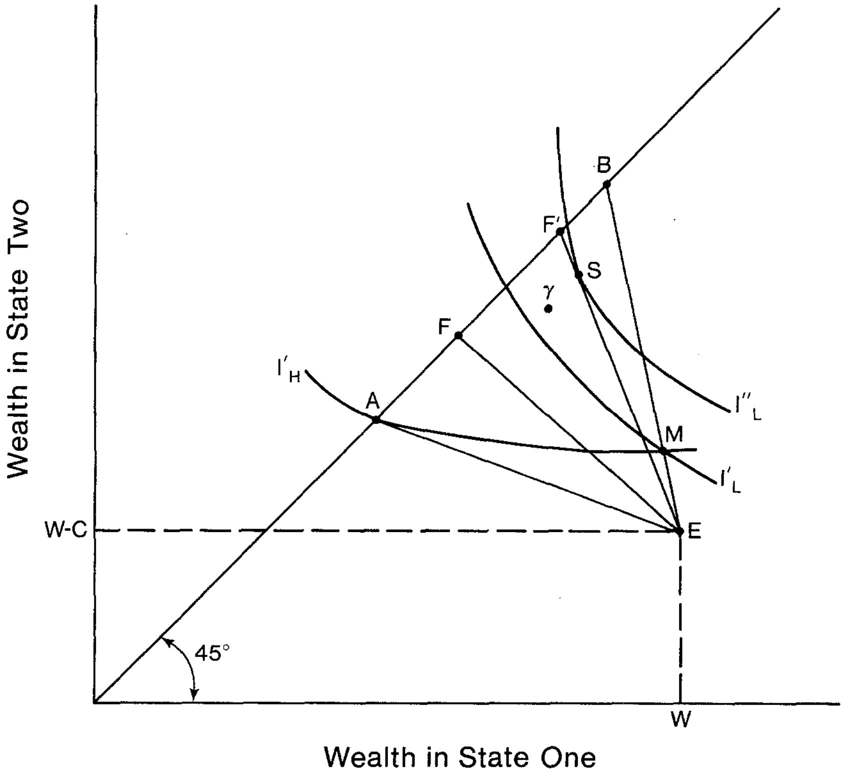

Figure 2.

policy γ which will have a positive expected profit. The policies A and M will be dropped and competition will reduce the expected profit on the pooling solution to zero. However, the preceding analysis showed that there is no pooling equilibrium and therefore a Nash equilibrium does not exist. However, if the market-odds line is FE, then the policies A and M satisfy the Nash equilibrium. Note that if a Nash equilibrium exists, both groups pay an actuarially fair premium. The high-risk group receives full coverage, and the low-risk group receives partial coverage.

A Nash equilibrium may fail to exist because it assumes that firms are myopic and do not take into account the effect of a new insurance policy on the policies offered by other firms. Wilson (1977) has introduced an alternative concept of equilibrium in which each firm correctly anticipates which policies will be dropped by other firms when it changes its menu of policies and has shown that an equilibrium will exist when the firm's expectations are modified in this manner. A set of policies is a Wilson equilibrium in a competitive insurance market if for each firm there is no policy or set of policies, J, which would earn a positive expected profit after other firms have withdrawn the policies which have been rendered unprofitable with the introduction of J. Miyazaki (1977) and Spence (1978) have shown that the Wilson equilibrium can be consistent with cross-subsidization between the policies offered by a firm to high-risk and low-risk individuals. They have shown that a Wilson equilibrium is the solution to the problem which maximizes the expected utility of a low-risk individual subject to the constraints given by (8), (9) and (10) where the latter equation replaces (6) and (7) in the problem on page 552 because it allows for cross-subsidization.

$$h((1-\pi_H)P_H - \pi_H V_H) + (1-h)((1-\pi_L)P_L - \pi_L V_L) = 0 \tag{10}$$

Miyazaki (1977: 410-412) has shown that there is a unique solution to this problem, and it involves a Wilson equilibrium with cross-subsidization when (9) is not binding, and the following condition holds:[5]

$$U'(L2) - U'(L1) = \frac{U'(L1)U'(L2)}{U'(H)} \cdot \frac{(\bar{\pi} - \pi_L)(\pi_H - \pi_L)}{\pi_L(1-\pi_L)(\pi_H - \bar{\pi})} \tag{11}$$

$$U(H) = \pi_H U(L2) + (1-\pi_H)U(L1) \tag{12}$$

where Lk is the wealth of a low-risk individual in state k and H is the wealth of a high-risk individual who receives full-coverage insurance. It should be noted that the Wilson equilibrium is Pareto optimal subject to the informational and financial constraints.

A Wilson equilibrium with cross-subsidization is shown in Figure 3. The line $A'ZR$ represents policies such that the expected loss is $\pi_H(RE)$ when it is

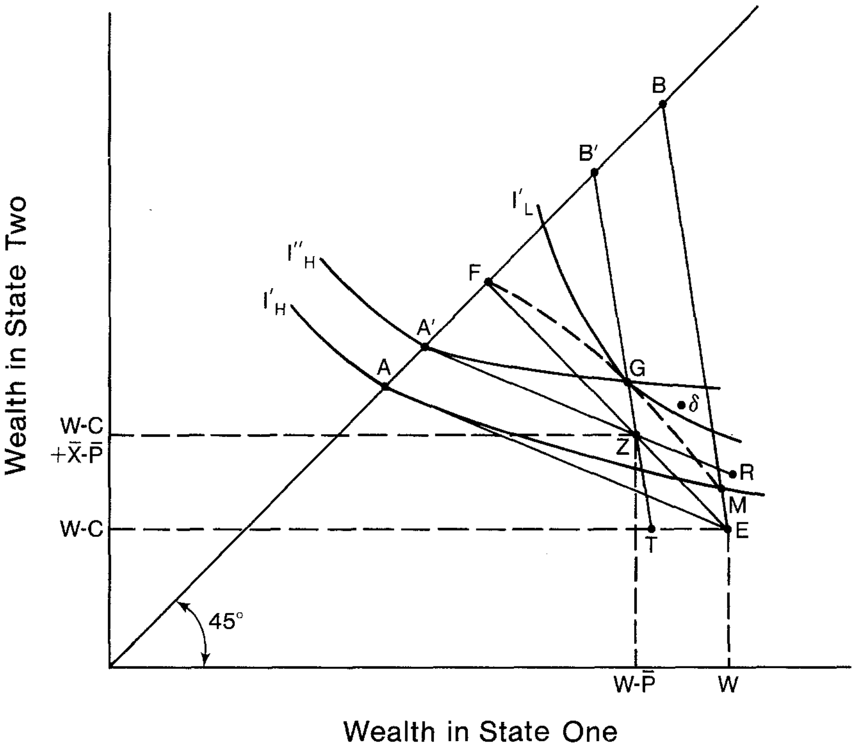

Figure 3.

purchased by a high-risk individual. The line $B'ZT$ represents policies such that the expected profit is $(1 - \pi_L)TE$ when it is purchased by a low-risk individual. The lines intersect at the point Z on the market-odds line which indicates that with the policy Z the expected profit is zero when it is purchased by both risk groups. Therefore any combination of policies with the high-risk group on $A'ZR$ and the low-risk group on $B'ZT$ will have an expected profit of zero. The optimal degree of cross-subsidization is found by varying the point Z along the market-odds line between F and E to obtain the locus of points such that the indifference curve of the high-risk group with the given subsidized full coverage policy intersects $B'Z$. This locus is the dashed line, FGM, and the optimal policies are A' and G. Note that the policies A' and G are Pareto superior to the policies under the Nash equilibrium A and M because I'_L cuts BE to the left of M. The Wilson and Nash equilibria will coincide if the optimal policy on FGM is the endpoint M.

This Wilson equilibrium exists because of the assumption that a firm anticipates the reactions of other firms to changes in its policy. No firm will drop its unprofitable policy A' because, if it did, other firms would also drop that policy and G would earn a negative expected profit because it would be purchased by high-risk individuals. Similarly no new firm would offer a policy such as δ because it would anticipate that the other firms would withdraw A' and G which would render δ unprofitable because it would be purchased by high-risk and low-risk individuals. Rothschild and Stiglitz (1976: 647) are sceptical about the relevance of the Wilson equilibrium for competitive markets because '... it is hard to see how or why any single firm should take into account the consequences of its offering a new policy. On balance, it seems ... that nonmyopic equilibrium concepts are more appropriate for models of monopoly (or oligopoly) than for models of competition.' Despite its shortcomings, the Wilson equilibrium provides insights which are very useful in analyzing the potential for Pareto improvements through compulsory insurance.

If a Nash equilibrium exists, then compulsory insurance which does not permit supplementary insurance will not be a Pareto improvement. Recall that the condition for the existence of a Nash equilibrium is that the indifference curve through the point M does not intersect the market-odds line as is the case in Figure 2 when FE is the market-odds line. Therefore compulsory insurance, which does not permit supplementary insurance, will lead to a wealth combination on the market-odds line which will make a low-risk individual worse off than they would be with the policies under the Nash equilibrium.

However, as Wilson (1977: 200) has noted, compulsory partial coverage insurance which permits private insurance companies to sell supplementary insurance may result in a Pareto improvement over the Nash equilibrium. This result is based on the fact that compulsory partial coverage insurance combined with supplementary insurance can produce a Nash equilibrium which duplicates the Wilson equilibrium with cross-subsidization. The optimal levels of compulsory and supplementary insurance for a low-risk individual subject to the financial and informational constraints satisfy the following problem:

$$\max_{\bar{X}, X_L, X_H} \quad (1-\pi_L)U(L_1) + \pi_L U(L2)$$

subject to

$$(1-\pi_H)U(H1) + \pi_H U(H2) \geq (1-\pi_H)U(L1) + \pi_H U(L2)$$

where

$$L1 = W - \bar{\pi}\bar{X} - \pi_L X_L$$

$$L2 = W - C + (1-\bar{\pi})\bar{X} + (1-\pi_L)X_L$$

$$H1 = W - \bar{\pi}\bar{X} - \pi_H X_H$$

$$H2 = W - C + (1 - \bar{\pi})\bar{X} + (1 - \pi_H)X_H$$

$$\bar{X} \geq 0, X_i \geq 0; \qquad i = H, L$$

where $\bar{X}$ is the compulsory insurance coverage purchased at the price $\bar{\pi}$ and X_i is the supplementary insurance coverage purchased by group i at the price π_i. With the optimal policies, high-risk individuals obtain full coverage ($C = \bar{X} + X_H$) and $\bar{X}$ and X_L satisfy equations (11) and (12) which are the same conditions which hold with the Wilson equilibrium.

In Figure 3, the policies with a Wilson equilibrium are A' and G. This solution could be duplicated if all individuals are required to carry insurance with an indemnity of $\bar{X}$ and premium of $\bar{P}$, which would be afforded by the compulsory insurance policy Z, and if firms are permitted to offer supplementary insurance. A competitive insurance industry will offer supplementary policies which give rise to wealth combinations along the lines $A'Z$ and $B'Z$. If the level of compulsory insurance is chosen so as to maximize the expected utility of a low-risk individual subject to the break-even and informational constraints a Nash equilibrium will occur with firms offering supplementary policies which give high-risk individuals full coverage at A' and low-risk individuals partial coverage at G. This will be a Nash equilibrium because the supplementary policies purchased by each risk group break-even, and there is no supplementary policy which, if offered, has a positive expected profit.[6] A policy such as δ which would be purchased by low-risk individuals but not by high-risk individuals would yield a negative expected profit. There is no supplementary policy which would be preferred by both risk groups and has a positive expected profit because the locus FGM always lies above the market-odds line FZ. Just as the Wilson equilibrium is Pareto superior to the Nash equilibrium, the optimal combination of compulsory partial coverage and supplementary insurance shown in Figure 3 represents a Pareto improvement over the Nash equilibrium because I_L', the indifference curve of a low-risk individual through the point G, intersects BE to the left of M. Note, however, that if the optimal wealth combination for a low-risk individual on the locus FGM is the point M, then any combination of compulsory and supplementary insurance will make the low-risk group worse off.

If a Wilson equilibrium exists with cross-subsidization of policies, then compulsory insurance will not result in a Pareto improvement. The Wilson equilibrium is Pareto superior to any level of compulsory insurance without supplementary coverage because the locus FGM lies above the market-odds line FE. As the above analysis has indicated, the optimal combination of compulsory and supplementary coverage for a low-risk individual will produce the same solution as the Wilson equilibrium. Therefore, no combination of compulsory and supplementary insurance will result in a Pareto improvement if a Wilson equilibrium with cross-subsidization exists.

NOTES

1. That is, the sum of the gains to the high-risk group exceed the sum of the losses sustained by the low-risk group from compulsory full coverage insurance financed by premiums or taxes based on the average expected loss. On this issue, see Dahlby (1979).
2. This diagram is based on the analysis of Rothschild and Stiglitz (1976).
3. Pauly and Johnson based their arguments on measures of consumer's surplus.
4. The analysis also shows that compulsory insurance does not necessarily lead to Pareto improvements because the point J could lie to the right of N on FE and the indifference curve I_L' could cut the 45 degree line to the right of F.
5. See also Dahlby (1980).
6. Spence (1977: 441) has noted that if the objective of government intervention is to maximize net social benefits, then '... the private market cannot be allowed to function along side the optimal social menu.' Within the context of our model, this objective implies that all individuals have full coverage, and the program will break-even if all individuals are at point F in Figure 3. Therefore, compulsory full coverage insurance is necessary because low-risk individuals prefer the policies offered by the private insurance market.

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