© The Journal of Risk and Insurance, 1996, Vol. 63, No. 3, 434–459.

Information Asymmetries and Informational Incentives in Monopolistic Insurance Markets

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ABSTRACT

This study considers a single-period monopolistic insurance market with adverse selection and moral hazard. We find that, where the distortions introduced by moral hazard are sufficiently moderate, the insurer can use price-quantity contracts as a mechanism to simultaneously deal with both information asymmetries. When no information regarding type is available, the problem is one of moral hazard with imperfect information regarding loss prevention productivity. We consider the consumer's incentive to acquire information regarding type and find that, with multiple types and nonzero optimal effort levels in the market, both pre-contract and post-contract information are valuable to consumers. Post-contract information cannot be used to separate types but does allow consumers to choose an optimal effort level. Although pre-contract information creates the adverse selection problem, consumer welfare increases because information allows modification of effort level and contract choice.

INTRODUCTION

The Pareto optimal allocations associated with competitive markets may not be reached whenever either hidden knowledge (adverse selection) or hidden actions (moral hazard) are present. One market in which both problems are frequently simultaneously present is the market for insurance. Monopoly provision of insurance occurs in a number of markets where adverse selection and moral hazard would be expected to occur simultaneously. For example, single-payer health insurance systems, monopoly workers' compensation systems, and social security (retirement income) systems frequently involve a single insurance provider.

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Dr. Ligon wishes to thank the College of Commerce and Business Administration and the Department of Economics, Finance and Legal Studies of the University of Alabama for their financial support. The authors thank an anonymous referee for helpful comments. A previous version of this article was presented at the 1993 American Risk and Insurance Association Annual Meeting.

Because of the analytical complexities involved, moral hazard and adverse selection are rarely considered simultaneously in economic models of insurance markets. Moral hazard introduces nonconvexities into both the consumer's indifference curves and the feasible (non-negative profit) contract set (Arnott and Stiglitz, 1988a). When combined with issues necessary to establish stable equilibria in the presence of adverse selection in competitive insurance markets (see Rothschild and Stiglitz, 1976; Wilson, 1977; Miyazaki, 1977; and Spence, 1978), the analytics can become quite difficult (see Arnott, 1991, for a discussion).

Recently, the literature has begun to explore markets where adverse selection and moral hazard are present simultaneously. For example, Laffont and Tirole (1986) and Picard (1987) consider the design of optimal incentive schemes in markets where adverse selection and moral hazard are simultaneously present, but they consider only risk-neutral agents. Baron and Besanko (1987) extend this line of research with risk-averse agents. The simultaneous presence of adverse selection and moral hazard in insurance markets has been considered by Dionne and Lasserre (1988), Hoy (1989), Bond and Crocker (1991), and Stewart (1994).[1] Dionne and Lasserre (1988) consider a monopoly insurer and multiple-period contracts and show that monitoring deviations of losses from the mean can detect deviation from efficient effort levels and lead to first-best allocations of risk. As in the current article, they show that self-selection may help solve moral hazard problems as well as adverse selection problems. Hoy (1989) focuses on the value of information in the presence of adverse selection and moral hazard. Bond and Crocker (1991) consider a case where the hidden information is a taste for a good whose consumption is correlated with the probability of loss. Stewart (1994) considers equilibrium in competitive insurance markets in the presence of adverse selection and moral hazard and focuses on the welfare effects when both problems are present in the market.

In this article, we consider the resolution of the informational problems of adverse selection and moral hazard by a monopoly insurer in a single-period setting. Our model of a monopoly insurer is a generalization of Stiglitz's (1977) adverse selection model. We show that, where the distortions introduced by moral hazard are sufficiently moderate so that the insurer's iso-profit loci are concave and the consumers' indifference curves are convex in state space, the insurer can design a mechanism which simultaneously addresses the issues of adverse selection and moral hazard by using price-quantity contracts. This mechanism shares many of the characteristics observed in the resolution of the pure adverse selection problem.

In addition, we consider whether the adverse selection problem can arise endogenously in this type of market by determining the value to the consumer of information regarding the consumer's type. Information can be acquired either before or after contracts are negotiated, and we consider both cases. Although we focus on the case of a monopoly insurer, our results on the value of information to

[1] An earlier article by Whinston (1983) considers adverse selection and moral hazard in the optimal provision of social insurance. However, Whinston's results appear less general in that they seem to depend on the specific (and somewhat curious) structure of asymmetric information assumed.

consumers generalize to other market settings. Post-contract information is valuable because it allows the level of effort or care to be chosen optimally. In the case of pre-contract information, the self-selection constraints also induce value on information. This extends earlier work by Crocker and Snow (1992), Doherty and Thistle (1996), and Ligon and Thistle (1996) on the value of information under adverse selection and by Boyer, Dionne, and Khilstrom (1989) and Hoy (1989) on the value of publicly available information under moral hazard.

The next section presents the assumptions surrounding the model. The third section considers the case where consumers are uninformed about type. In this context, the informational problem is that of moral hazard with imperfect knowledge regarding loss prevention productivity. The fourth section considers the case where consumers can become informed after contracting with the insurer. The nature of an informed equilibrium and the value of information are considered. The fifth section considers the case where consumers can become informed about type before contracting with the insurer. We explore the form of an informed equilibrium, which involves the simultaneous resolution of the adverse selection and moral hazard problems, and consider the value of information to the consumer and insurer. A final section summarizes and concludes the study.

Analytical Framework

There are two possible states of the world, loss (L) and no loss (N). Consumers have initial wealth W_0 and may suffer a loss of $\ell < W_0$. We assume that ℓ is fixed, so that moral hazard affects only the probability of loss, p. Nature has previously chosen consumers to be one of two types, A (adept) and B (bungling). Let $\theta(1 - \theta)$ represent the proportion of consumers of type B (A), which is common knowledge. Both types of consumers may choose an effort (care) level e from a closed interval which, without loss of generality, we take to be the unit interval [0, 1]. The probability of loss is then a function of the effort level chosen. We assume that $1 > p_B(e) \geq p_A(e) > 0$ for all $e \in [0, 1]$. We sometimes refer to $p_i(0)$ as the base probability of loss. We also assume that the $p_i(e)$ are twice continuously differentiable with $0 > p'_B(e) > p'_A(e)$ and $p_i''(e) > 0$. That is, effort by type As is relatively more productive at reducing the loss probability than effort by type Bs. Note, for $e > 0$, $p_B(e) > p_A(e)$.[2] Consumers maximize the expected value of u(w) –

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[2] The model is similar to the increasing difference case considered by Hoy (1989) and produces analytical results similar to the model of Stewart (1994). The specification was chosen because it seems appropriate for most property-liability insurance markets. Careless individuals likely have high probability of loss, irrespective of their innate abilities, but as individuals exercise care we would expect some people's loss prevention efforts to be more productive than others (i.e., the difference between individuals' loss probabilities is increasing in effort). A specification where individuals' loss probabilities innately differs but where effort reduces those differences (i.e., $p_B(0) > p_A(0)$ with $p'_B(e) < p'_A(e) < 0$; see Dionne and Lasserre, 1988, and Hoy's decreasing difference case, for example) might be appropriate for life (and possibly health) insurance markets. Such a specification would clearly change the nature of the optimal contracts, but as long as the single crossing property of indifference curves holds, so that the adverse selection problem can be solved, the analysis goes through, although the modification of effort levels in response to information will differ. However, if $p'_A(e) = p'_B(e)$ (Hoy's constant difference case), the value of post-contract information is zero, and the value of pre-

v(e), an additively separable von Neumann-Morgenstern utility function over wealth, w, and effort, e. The utility of wealth is $u(\cdot)$, where u is continuously differentiable with $u'(\cdot) > 0$, $u''(\cdot) < 0$. The disutility of effort is $v(\cdot)$, with $v'(e) > 0$ and $v''(e) > 0$ and $v'(e) \to \infty$ as $e \to 1$. We normalize $v(0) = 0$.

An insurance policy, $C = (\alpha, \beta)$, is described by a premium, α, and the net indemnity in the event of a loss, β. We assume that the parties to the insurance contract are committed to its terms and not permitted to renegotiate.[3] Expected utility of wealth for any consumer with probability of loss p_i choosing effort level e and insurance policy $C_j = (\alpha_j, \beta_j)$ is

$$U_i(C_j, e) = p_i(e)\, u(W_0 - \ell + \beta_j) + (1 - p_i(e))\, u(W_0 - \alpha_j) - v(e). \qquad (1)$$

We are concerned with consumers whose loss probabilities are p_A, p_B, and $p_\mu = (1 - \theta)p_A + \theta p_B$. At the consumer's endowment, no insurance is purchased ($C_0 = (0, 0)$), and we let $U_i(\mathbf{0}, e)$ denote expected utility at the endowment of a type i consumer when the effort level is e. We assume that, at the endowment, individuals who exercise positive care ($e > 0$) have higher utility than those who do not ($e = 0$), irrespective of type.

We assume throughout the analysis that the consumer's effort level is unobservable and is chosen to maximize expected utility. The consumer's effort level satisfies the first-order condition

$$-p'_i(e)[u(W_0 - \alpha_j) - u(W_0 - \ell + \beta_j)] = v'(e). \qquad (2)$$

Given the insurance contract $C_j = (\alpha_j, \beta_j)$, the effort level that solves equation (2) and maximizes expected utility is $\hat{e}_j = \hat{e}(C_j)$.[4] The corresponding loss probability for a type i consumer is $p_i(\hat{e}_j)$.[5] Then, for a type i consumer, the contract C produces a maximum expected utility level of $\max_e U_i(C_j, e) = U_i(C_j, \hat{e}_j)$. Similarly, at the endowment a type i consumer achieves a maximum utility level of $\max_e U_i(\mathbf{0}, e) = U_i(0, \hat{e}_0)$.

Assume a risk-neutral, profit-maximizing monopoly insurer.[6] The adverse selection problem with no moral hazard has been analyzed by Stiglitz (1977).

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contract information is related solely to the adverse selection problem and can be determined as suggested in Ligon and Thistle (1996).

[3] When quantity rationing is used to reveal hidden information by self-selection, the parties to the contract have an interest in renegotiating its terms once the information is revealed. However, if renegotiation is anticipated, the self-selection mechanism is no longer reliable. We do not wish to consider these issues here. See Dionne and Doherty (1994) for a discussion.

[4] That is, $\hat{e}_j = \arg\max_e p_i(e)u(W_0 - \ell + \beta_j) + (1 - p_i(e))u(W_0 - \alpha_j) - v(e)$.

[5] Under the assumptions on the loss probabilities and disutility of effort, expected utility is strictly concave in effort given the insurance policy. Thus, ê is a unique global maximum and is continuously differentiable in the premium and indemnity. Also, the model meets the conditions of Rogerson (1985) regarding the first-order approach.

[6] Many contexts where monopoly provision actually occurs involve social insurance. In these contexts, the assumption of profit maximization may seem inappropriate. However, the resolution of the moral hazard problem traditionally involves maximizing the utility of the principal (as a function

Stiglitz's adverse selection model can be viewed as the special case where $p_B(0) > p_A(0)$ and effort is unproductive ($p'_A(e) = p'_B(e) = 0$). Hence, consumers always choose zero effort and receive expected utility $U_i(C_j, 0)$. Stiglitz (1977) has shown that the insurer's problem is to find the contract set that solves the following problem:

$$\max_{\alpha_i, \beta_i, \lambda_i, \gamma_{ij}} \sum_i q_i \{(1 - p_i)\alpha_i - p_i \beta_i\}, \tag{3}$$

where q_i is the number of policies sold to consumers of type I, and α_I and β_i represent the premium and net indemnity, respectively, of the contracts purchased by type i. The insurer is subject to the individual rationality or participation constraints

$$U_i(C_i, 0) - U_i(\mathbf{0}, 0) \geq 0, \quad \forall\, i \tag{4}$$

with Lagrange multipliers λ_i and the incentive compatibility or self-selection constraints

$$U_i(C_i, 0) - U_i(C_j, 0) \geq 0, \quad \forall\, i, j, \tag{5}$$

with Lagrange multipliers γ_{ij}. The constraint (4) implies that consumers of all types prefer participation in the market to their endowment, and the constraint (5) implies that consumers prefer policies designed to appeal to their type to policies designed to appeal to other types.

When both moral hazard and adverse selection are present, the revised problem modifies equation (3) by making p_i a function of α and β through the choice of effort level e and incentive compatibility requires two sets of constraints: truth telling (with Lagrange multiplier γ_{ij}) and effort level (with Lagrange multipliers ζ_{ij}). Thus, equation (3) becomes

$$\max_{\alpha_i, \beta_i, \lambda_i, \gamma_{ij}, \zeta_i} \sum_i q_i [(1 - p_i(e_i))\, \alpha_i - p_i(e_i)\beta_i]. \tag{6}$$

Letting C_{ie} be any contract designed by the insurer to appeal to a type i consumer exercising effort level e, the participation constraints become

$$U_i(C_{ie}, \hat{e}_i) - U_i(\mathbf{0}, \hat{e}_0) \geq 0, \quad \forall\, i. \tag{7}$$

of the principal's monetary payoff) assuming that the agent will maximize his or her own utility over the available actions given the incentive scheme that the principal introduces. As for the objective function of the social insurer, we assume that, if the monopoly provider is a social insurer, it will behave as a profit maximizer in order to create the appropriate moral hazard–reducing incentives. We assume that the government may undertake lump sum transfers outside the insurance market as appropriate to maximize the overall social welfare function, but that consumers perceive no connection between these transfers and the effort levels they choose with respect to the insurable risk, perhaps because they are randomized (see Arnott and Stiglitz, 1988b).

The truth telling constraints become

$$U_i(C_{ie}, \hat{e}_i) - U_i(C_{je}, \hat{e}_j) \geq 0, \quad \forall\ i, j, \tag{8}$$

and the effort level constraints can be written as the first-order condition

$$-p'_i(e)[u(W_0 - \alpha_j) - u(W_0 - \ell + \beta_j)] = v'(e) \quad \forall\ i, j. \tag{9}$$

Equation (7) states that the contracts intended by the insurer for particular types cannot leave those types of consumers worse off than they were with optimal effort levels at the endowment. Equation (8) states that contracts intended for particular types must sort the consumers by type, given optimal effort levels at the contracts. Equation (9) states that the consumer will, after selecting the contract, exercise the optimal effort level, which corresponds to that expected by the insurer.

The situation presented involves a generalized principal-agent problem which may be treated as a hybrid between a cooperative and a noncooperative game. The agents (consumers) will act noncooperatively as utility maximizers who will accept any Nash equilibrium of the game which the principal (insurer) chooses. The principal's problem is to design a mechanism that maximizes the principal's utility, which in this case is linear in profit. The situation is thus a Bayesian game with incomplete information (see Harsanyi, 1967, 1968a, 1968b).

Myerson (1982) notes that computing the equilibria of any such game can often be extremely difficult, but that the class of all outcomes which the principal can achieve as Bayesian equilibria of these games is actually quite easy to characterize. Myerson (1982, 1985) shows that the principal can restrict itself to incentive-compatible direct coordination mechanisms, in which agents participate and truthfully reveal their private information to the principal and take the actions that the principal desires, given the private information revealed. Postlewaite and Schmeidler (1986) raise the point that there may be difficulties in implementing such incentive-compatible direct coordination mechanisms. However, Palfrey and Srivastava (1989) show that such mechanisms are implementable in private value models, such as the one under consideration here, if restrictions are placed on the agents' strategy spaces such that agents do not use weakly dominated strategies in equilibrium.

In the current context, Myerson's results imply that the principal can do no better than offering contracts where the participation constraint binds for those types with the highest utility at the endowment, the self-selection constraints bind to separate types, and the effort level that maximizes the utility of the consumer, given the contract chosen by a particular type, is the effort level that the principal intends. The Palfrey and Srivastava modification effectively implies that, when constraints bind, agents do what the principal desires, an assumption that has been commonly made in adverse selection models from Rothschild and Stiglitz (1976) forward. In the current context, this implies that, when indifferent between two contracts, the insured chooses the contract preferred by the insurer; when indifferent between a contract and the endowment, an insured chooses the contract;

and when the value of costless information is zero, the insured chooses to become informed.

In the original adverse selection problem posed by Stiglitz, a consumer's type, and therefore loss probability, was exogenous. Here, the consumer's type is predetermined by nature, but the loss probability is a function of the level of effort chosen. The consumer's ability to influence the loss probability through a choice of care level will change the nature of the consumer's utility maximization problem. This, in turn, changes the specific contracts offered by the insurer, as the insurer now attempts to influence the consumer's level of care. However, this distinction does not change the basic characterization of the insurer's solution to the profit maximization problem. The insurer must continue to separate consumers by designing contracts that induce individuals to exercise appropriate care levels and, where appropriate, to reveal their types. The interaction between contract and type simply places additional constraints on the solution space. The constraints can make the problem analytically complex because moral hazard may introduce nonconvexities into both the consumer's indifference curves and the insurer's zero profit locus (Arnott and Stiglitz, 1988a). However, as Stewart (1994) notes, the insurer's profit loci will be well behaved as long as the base loss probability (at zero effort) or the convexity of v is sufficiently large, and the consumer's indifference curves will be well behaved as long as v" is sufficiently large or the consumer is sufficiently risk averse. We assume that those conditions hold here.

The following analysis shows that, even with the modified optimization problem and the additional constraints, in our economic environment, the incentive-compatible direct revelation mechanism designed by the insurer still produces a solution with the following characteristics similar to those observed by Stiglitz in the pure adverse selection case:

(1) The policy accepted by the individuals in the best risk class extracts their entire consumer's surplus.

(2) Any policy accepted by the individuals who exert no effort involves full coverage.

(3) For any individuals exercising positive care levels, coverage is partial. The level of coverage available becomes progressively smaller for better risk classes.

(4) If signaling costs are too high (whether because of a large number of poor risks or a large number of classes) the insurer's profit maximization forces contract offerings such that better risks may prefer their endowment (i.e., they do not participate in the market).

Moral Hazard with No Information Regarding Type

We wish to study the interaction of adverse selection, moral hazard, and the acquisition of information. We initially assume that neither consumers nor insurers can observe the consumer's type. In this situation, consumers cannot determine whether their probability of loss is in fact $p_B(e)$ or $p_A(e)$. The only informational problem present in this market is moral hazard with imperfect information regarding type. The consumer's prior estimate of the loss probability is based on the overall market average, which is the only available information. We show that partial coverage can be used to induce individuals to exercise the appropriate care level for the policy chosen.

Given the form of the consumer's utility function, the consumer's maximization problem is equivalent to maximizing expected utility with the probability of loss set equal to $p_\mu(e) = \theta p_B(e) + (1 - \theta)p_A(e)$, where $0 \leq \theta \leq 1$ is the probability that any consumer is type B. For a given level of loss prevention productivity, there exists a family of policies with monotonically increasing coverage which generate constant utility equal to that of the endowment and which correspond to a monotonically decreasing post-purchase utility maximizing level of effort. The insurer maximizes profits in this situation by offering a policy, $C_{\mu*} = (\alpha_{\mu*}, \beta_{\mu*})$, along this variable effort indifference curve such that individuals are just indifferent between this policy and their endowment, and, after buying this policy, individuals will exercise the care level intended by the insurer. The particular premium and indemnity chosen are the ones maximize the insurer's profit and induce care level, $\hat{e}_{\mu*}$. That is, the insurer solves the following program:

$$\max_{\alpha_\mu, \beta_\mu, \lambda_\mu, \zeta_\mu} q[(1-p_\mu(\hat{e}_\mu)\,\alpha_\mu - p_\mu(\hat{e}_\mu)\beta_\mu] \tag{10}$$

subject to the participation constraint

$$U_\mu(C_{\mu*}, \hat{e}_{\mu*}) - U_\mu(\mathbf{0}, \hat{e}_0) = 0, \tag{11}$$

with Lagrange multiplier λ_μ and the effort level constraints

$$-p'_\mu(\hat{e}_\mu)[u(W_0 - \alpha_\mu) - u(W_0 - \ell + \beta_\mu)] - v'_\mu(\hat{e}_\mu) = 0 \tag{12}$$

$$-p'_\mu(\hat{e}_0)[u(W_0) - u(W_0 - \ell)] - v'_\mu(\hat{e}_0) = 0 \tag{13}$$

with Lagrange multipliers ζ_{μ} and ζ_0, respectively.[7] The Lagrangian and first-order conditions for this problem are presented in the Appendix.

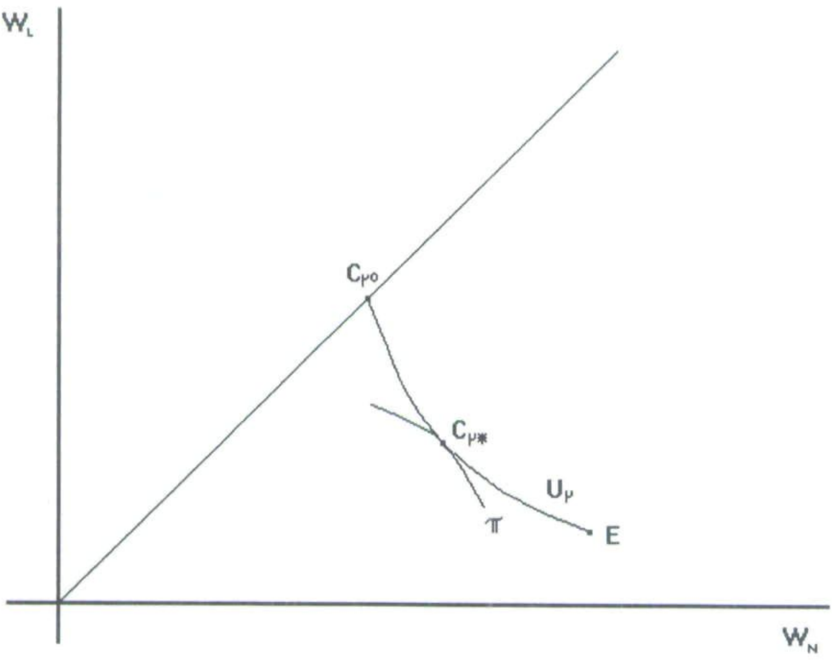
Figure 1 depicts the equilibrium in the current (no information) case in state space. W_N represents wealth in the no-loss state and W_L represents wealth in the loss state. The 45-degree line through the origin corresponds to full insurance. The endowment (no insurance) is represented by E. The curve U_μ represents the variable effort indifference curve through the endowment for consumers who do not know their type and estimate their loss prevention possibilities at the population average. The curve π represents a variable effort-isoprofit locus for the insurer. The contract $C_{\mu*}$, representing the profit maximizing contract for the insurer, is on the variable effort indifference curve through the endowment at the

[7] Since the problem has been written in first-order condition form, the effort level constraints are technically redundant here. We include them as a reminder of the definitions of $\hat{e}_\mu$ and $\hat{e}_0$. We use $v'_i(\hat{e}_j)$ to denote the marginal disutility of optimal effort of a type i at contract j.

insurer isoprofit locus intersecting this curve that is closest to the origin (i.e., at the tangency).

Types B and A can be successfully pooled at $C_{\mu*}$ because the consumers themselves cannot distinguish their type. The actual premium and net indemnity, $\alpha_{\mu*}$ and $\beta_{\mu*}$, depend upon the average productiveness of self-protection, $p'_{\mu}(e)$, the degree of risk aversion (i.e., form of u), and the disutility of effort function, v(e). Since the base probability provides an upper limit to p, there is nothing to preclude a solution involving full insurance and zero effort levels. Greater risk aversion and disutility of effort will tend to push the profit maximizing solution toward the full insurance–zero effort contract. Greater productivity of self-protection will tend to push the profit maximizing solution toward the endowment. Since the participation constraint (11) is binding and there is a single contract purchased in equilibrium, the insurer captures all of the consumer's surplus for each consumer.

Figure 1
Equilibrium in the No Information Case in State Space



Post-Contract Information Regarding Type

We now consider cases where individuals are initially uninformed but can choose to obtain information regarding their type. We assume that the insurer cannot observe the consumer's informational (informed/uninformed) status, and, if consumers become informed, the insurer cannot observe consumers' types. Thus, insurance opportunities cannot be conditioned on informational status. Ligon and Thistle (1996) have shown that, in a market with adverse selection alone, information regarding type will have non-negative value to consumers facing a choice over any fixed contract set. We now consider whether a similar result holds when adverse selection and moral hazard are simultaneously present. Although in designing its mechanism the insurer is the first mover, an insurer with rational expectations that knows that information is available to consumers but cannot observe the informational status of the consumer or the information itself, must, when making its contract offerings, consider the consumer's incentive to acquire information. We begin by considering the case where information may be observed after contracting but prior to choice of care level. In the case where information is received after contracting but before the exercise of care, information can influence only the level of care taken and not the policy choice. Thus, self-selection cannot be used to reveal type. This case is relevant to the example of the social insurer, which, for public policy reasons, pools individuals at a single price and quantity.

We begin by considering a consumer's incentive to learn her type. The value of information to a consumer is the expected change in utility from acquiring the information. If the policyholder is uninformed, the insurance policy is evaluated and level of care is chosen based on the loss probability p_μ, which yields expected utility $U_\mu(C, \hat{e})$. If the policyholder is informed and knows she is type A (B), the insurance policy is evaluated and level of care is chosen based on the loss probability p_A (p_B); this yields expected utility $U_A(C, \hat{e})$ ($U_B(C, \hat{e})$). *Ex ante*, the consumer will learn she is type A with probability $(1 - \theta)$ and learn she is type B with probability θ. It follows that, for any policy C, the value of information is

$$I(C) = \theta U_B(C, \hat{e}) + (1 - \theta)\, U_A(C, \hat{e}) - U_\mu(C, \hat{e}), \tag{14}$$

for $0 \leq \theta \leq 1$.

For a single contract offering, the value of knowing one's type is that the true productivity of loss prevention effort is known. This allows one to adjust one's effort level appropriately. If one learns that effort is more (less) productive at loss prevention than previously believed (i.e., p' is more (less) negative than previously believed), the optimal response will be to increase (decrease) effort. From equation (2), the required modification of p' will be relatively smaller the larger is β (the coverage level). Thus, the increase in utility obtained by the consumer from modifying effort is greater at lower coverage levels.

If C is a policy offering full insurance (therefore inducing zero effort), then $I(C) = 0$. If θ equals zero or one, irrespective of the level of coverage, then there is only one type of consumer in the market, and $I(C) = 0$. Suppose that $0 < \theta < 1$, and the policy C offers less than full coverage (therefore inducing positive effort). Let $\hat{e}_{ij}$ represent the effort level that solves equation (2) for type i at contract j. Since $p'_A < p'_\mu < p'_B$, it follows from equation (2) that, for contract C, $\hat{e}_{AC} > \hat{e}_{\mu C} > \hat{e}_{BC}$. Then, by the definition of a maximum,

$$U_i(C, \hat{e}_{iC}) > U_i(C, \hat{e}_{\mu C}), \quad i = A, B. \tag{15}$$

The value of information is then $I(C) > 0$.[8] The value of information is the utility gain from the ability to adjust effort levels optimally given the insurance policy. In general, since $p'_A < p'_B$ for positive effort levels, we have $\partial I/\partial\beta < 0$, $\forall\ \beta < \ell - \alpha$ and $0 < \theta < 1$.

If consumers cannot acquire information until after contracts are negotiated, then there is only a single type of consumer at the time contracts are negotiated. It follows that, regardless of the market setting or equilibrium concept, only a single insurance policy will be offered. The market setting or equilibrium concept determines which policy will be offered and the division of surplus between insurers and consumers. But as long as a single policy is offered, post-contract information has non-negative value, and consumers have an incentive to become informed.

The program that the insurer must solve must take into consideration that consumers will become informed after making their contract choice. This modifies the insurer's profit maximization problem as follows:

$$\max_{\alpha_d, \beta_d, \lambda_i, \zeta_i} \sum\nolimits_{i=A,B} q_i[(1 - p_i(\hat{e}_d))\alpha_d - p_i(\hat{e}_d)\beta_d] \tag{16}$$

subject to the participation constraints

$$U_i(C_d, \hat{e}_d) - \hat{U}_i(\mathbf{0}, \hat{e}_0) = 0, \quad i = A, B \tag{17}$$

with Lagrange multipliers λ_i and the effort level constraints

$$-p'_i(\hat{e}_d)[u(W_0 - \alpha_d) - u(W_0 - \ell + \beta_d)] - v'_i(\hat{e}_d) = 0 \tag{18}$$

$$-p'_i(\hat{e}_0)[u(W_0) - u(W_0 - \ell)] - v'_i(\hat{e}_0) = 0, \quad i = A, B. \tag{19}$$

with Lagrange multipliers ζ_{ij}. The Lagrangian and first-order conditions for this problem are presented in the Appendix.

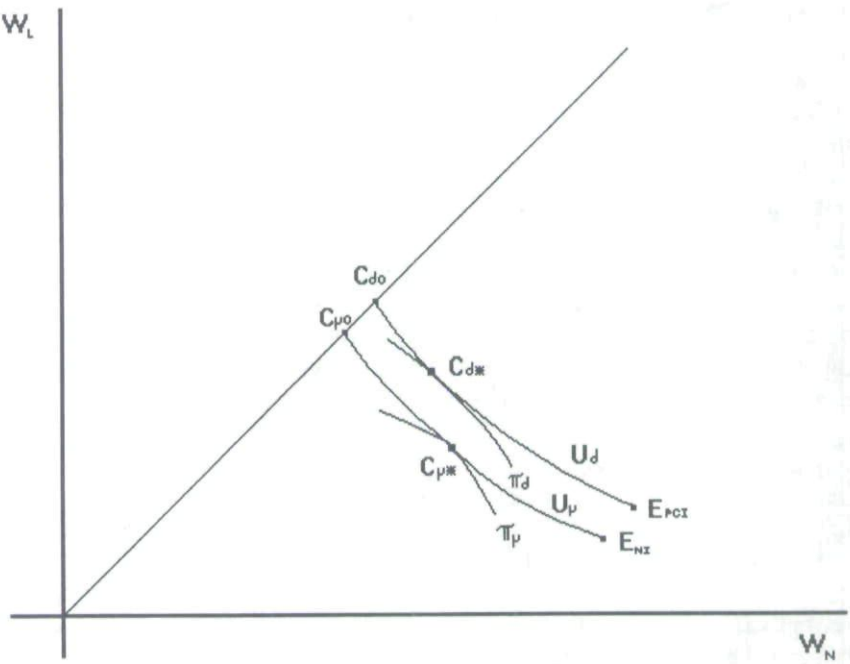
The policy $C_{\mu*}$ maximizes the monopoly insurer's profit given that policyholders are uninformed. Since the value of information at $C_{\mu*}$ is non-negative, consumers will choose to become informed. Then attempts by the insurer to offer $C_{\mu*}$ will be unsuccessful. This follows directly from equations (11) and (15) (which hold at $C_{\mu*}$ and $\mathbf{0}$) and the fact that changes in effort levels generate more utility at lower coverage levels. Together, these imply that consumers who can obtain post-contract information will prefer their endowment to the policy $C_{\mu*}$.

Post-contract information is effectively like an increase in the individual's endowment. For any $0 < \theta < 1$, $I(\mathbf{0})$ represents the increase in utility from being able to choose the appropriate care level at the endowment and is positive. The

[8] Inequality (15) holds as long as C offers less than full coverage, $0 < \theta < 1$, and $p'_A(\hat{e}_C) \neq p'_B(\hat{e}_C)$. If $p'_A > p'_B$, then $\hat{e}_{AC} < \hat{e}_{\mu C} < \hat{e}_{BC}$, but $I(C) > 0$ still holds. If $p'_A(C) = p'_B(C)$, $I(C) = 0$.

participation constraint (17) implies that any contract offered to a type must make the type at least as well off as they are at the endowment. Thus, the variable effort indifference curve for individuals with post-contract information must lie everywhere above the variable effort indifference curve for the no information case. Even though the benefit from adjusting effort levels is greatest at low levels of coverage, higher coverage contracts must reflect the value of effort adjustment at the endowment in order to encourage participation. This suggests that the variable effort indifference curve of individuals with post-contract information, U_d, lies in relation to the variable effort indifference curve for individuals with no information, U_μ, as indicated in Figure 2.

Figure 2
Equilibrium for Individuals with Post-Contract Information Compared to that for Individuals with No Information



In order to assess how post-contract information impacts the insurer's variable effort profit locus, we begin by reexamining the first-order condition for effort. For uninformed consumers, this is

$$-p'_\mu(e)[u(W_0 - \alpha_\mu) - u(W_0 - \ell + \beta_\mu)] = v'(e).$$

When consumers learn their types, they will substitute in their respective loss prevention functions. Since α and β are fixed for any C_{de}, for a given e, for type A consumers we have $p'_A(e) < p'_\mu(e)$, and for type Bs we have $p'_B(e) > p'_\mu(e)$. Since $p_i'' > 0$, this implies that, to optimize their own utility at C_{de}, type A consumers must increase their effort levels, while type Bs must decrease their effort levels. Since $v'' > 0$, the increase in effort required by type A consumers is smaller than the decrease in effort required by type Bs. Also, $p_i'' > 0$ implies that the decrease in the probability of loss resulting from a given increase in effort will be smaller than the increase in the probability of loss resulting from a given decrease in effort. Finally, $p_i'' > 0$ implies that the adjustments in effort levels will be greater the higher the optimal no information effort level (i.e., the lower the level of insurance coverage). Taken together, these facts imply that (1) the change in effort levels has a negative effect on insurer profits relative to the same contract with no information, (2) the change in profits per dollar of coverage is smaller at higher coverage levels, and (3) the change in profits per dollar of coverage is greater at lower coverage levels but, with less coverage, the overall change in profits may be smaller. This suggests that the insurer's variable effort-level profit loci in state space may be somewhat steeper and relatively less concave than in the no information case, as drawn in Figure 2.

The joint impact of the effects on variable effort indifference curves and variable effort-level profit loci, suggests that the likely impact of post-contract information is to increase the optimal coverage level and to decrease effort levels. At higher coverage levels, the optimal adjustment of effort levels is smaller and the detrimental effect on insurer profits per dollar of coverage is relatively smaller. This result may provide an explanation of why the cost of social insurance programs that involve pooling of the population frequently exceed preliminary cost estimates. If the cost estimates were prepared based on the expected population probability of loss for a population which previously faced type-dependent effort incentives, such estimates would understate the true probability of loss under the effort incentives applicable in the post-contract information case.

The profit maximizing contract, C_{d*}, depicted in Figure 2, occurs at the tangency of the insurer's variable effort-level profit locus and the variable effort indifference curve through the post-contract information endowment, E_{PCI}. E_{PCI} represents the endowment under post-contract information. E_{NI} represents the endowment with no information as to type. E_{PCI} lies northwest of E_{NI} along a line at a 45-degree angle to the abscissa. The distance between the two points represents the value of information, measured in wealth, in state space. It effectively represents the amount that an individual would accept to remain ignorant of his or her type. At C_{d*}, both types will choose the effort level that maximizes their utility given the contract purchase. Type A consumers will exercise relatively higher effort levels and generate relatively higher profits (or smaller losses). Type Bs will exercise relatively lower effort levels and generate relatively lower profits (or higher losses). Because type is learned only after contracting, contracts cannot be used to create a separating equilibrium.

In the event that $C_{\mu 0}$ maximizes insurer profits in the no information case, the form of the shift in the insurer profit locus suggests that it is likely that C_{d0} will maximize insurer profits in the post-contract information case. Although consumers will still prefer to exercise no effort after purchasing C_{d0}, C_{d0} must still reflect the value of post-contract information (i.e., it must have a lower premium than $C_{\mu 0}$) or consumers would elect not to participate in the market.

PRE-CONTRACT INFORMATION REGARDING TYPE

In this section, we consider the case where information is observed prior to contracting and choice of care level. As in the case of post-contract information, the value of this information to consumers is an important concern. If information has non-negative value to consumers, then adverse selection will arise endogenously in addition to the moral hazard problem. If information has negative value, then adverse selection does not arise, and the insurer need only control the moral hazard problem.

We assume that the consumer can observe a signal that perfectly reveals the consumer's type prior to contracting. As before, we assume informational status is unobservable by the insurer and, hence, insurance contracts cannot be conditioned upon a consumer's informational status. As in the preceding section, even though the insurer cannot observe the informational status of the consumer, the insurer must, when making contract offerings, consider the consumer's incentive to acquire information.

The value of information to consumers is the *ex ante* change in utility from acquiring the information. Suppose the insurer assumes consumers will become informed and offers a set of policies $\{C_A, C_B\}$ that satisfy the self-selection constraints for informed consumers

$$U_A(C_A, \hat{e}_A) - U_A(C_B, \hat{e}_B) \geq 0, \tag{20}$$

and

$$U_B(C_B, \hat{e}_B) - U_B(C_A, \hat{e}_A) \geq 0. \tag{21}$$

If consumers choose to remain uninformed, they will choose the policy C_A.[9] This induces the effort level $\hat{e}_{\mu A}$ yielding the estimated loss probability $p_\mu(\hat{e}_A)$ and expected utility of $U_\mu(C_A, \hat{e}_A)$ to uninformed consumers. If the policyholder is informed and knows she is type A, the insurance policy C_A and level of care $\hat{e}_{AA}$ are chosen, yielding the loss probability $p_A(\hat{e}_A)$ and expected utility $U_A(C_A, \hat{e}_A)$. Similarly, if the policyholder is informed and knows she is type B, the insurance policy C_B and level of care $\hat{e}_{BB}$ are chosen, yielding the loss probability $p_B(\hat{e}_B)$ and expected utility $U_B(C_B, \hat{e}_B)$. *Ex ante*, the consumer will learn she is type A with probability $(1 - \theta)$ and learn she is type B with probability θ. It follows that, for any set of policies $\{C_A, C_B\}$ that satisfy the self-selection constraint, the value of information is

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[9] As Myerson (1985) points out, type Bs "jeopardize" type As in the sense that Bs gain from imitating As, but As do not gain from imitating Bs. This implies that the self-selection constraint separating the Bs from the As will be binding, but the constraint separating the As from the Bs will not (i.e., As will strictly prefer C_A to C_B). Then uninformed consumers will strictly prefer C_A to C_B.

$$I(C_A, C_B) = \theta U_B(C_B, \hat{e}_B) + (1 - \theta)\, U_A(C_A, \hat{e}_A) - \hat{U}_\mu(C_A, \hat{e}_A), \tag{22}$$

for $0 \leq \theta \leq 1$. Observe that, if $C_A = C_B$, then equation (22) reduces to equation (14).

In order to determine the value of information, first observe that, if θ equals zero or one, then there is only one type of consumer in the market, and the value of information is zero. Suppose that $0 < \theta < 1$. Then, from equation (1) and the definition of p_μ, we have $U_\mu(C_A, \hat{e}_{\mu A}) = \theta U_B(C_A, \hat{e}_{\mu A}) + (1 - \theta)U_A(C_A, \hat{e}_{\mu A})$, where $\hat{e}_{ij}$ implies the solution to equation (2) for a type i choosing contract j. Then the value of information can be rewritten as

$$I(C_A, C_B) = \theta[U_B(C_B, \hat{e}_{BB}) - U_B(C_A, \hat{e}_{\mu A})] + (1 - \theta)[U_A(C_A, \hat{e}_{AA}) - U_A(C_A, \hat{e}_{\mu A})]. \tag{23}$$

Consider the second term, for the type A consumers. Since $\hat{e}_{AA} \neq \hat{e}_{\mu A}$, it follows from the definition of a maximum that the second term in equation (23) is positive. Now consider the first term in equation (23), for the type B consumers. From the self-selection constraint, we have $U_B(C_B, \hat{e}_{BB}) \geq U_B(C_A, \hat{e}_{BA})$. Since $\hat{e}_{BA} \neq \hat{e}_{\mu A}$, it follows from the definition of a maximum that $U_B(C_A, \hat{e}_{BA}) > U_B(C_A, \hat{e}_{\mu A})$. Combining these inequalities yields $U_B(C_B, \hat{e}_{BB}) - U_B(C_A, \hat{e}_{\mu A}) > 0$, so that the first term in equation (23) is positive. The value of information is then $I(C_A, C_B) > 0$.[10]

The intuition behind the preceding result is straightforward. When multiple types exist, with information one can modify one's choice of insurance policy and one's effort level. As in the case of post-contract information, the ability to adjust effort levels optimally, given the insurance policy, makes information valuable. In addition, the ability to choose a preferred policy also makes information valuable. When multiple types exist and multiple policies are available, the decision to become informed, in effect, leads to a lottery over policies. Since insurance contracts cannot be conditioned on informational status, the consumer cannot be forced to accept a policy that he or she regards as worse than the policy obtained when uninformed, and the consumer will (with positive probability) choose a policy that he or she regards as strictly better. The result that the value of information is positive does not rely on the assumption of a monopoly insurer, but holds for any pair of contracts that satisfy the self-selection constraints (20) and (21). Combining $I(C_A, C_B) \geq 0$ and $I(C) \geq 0$, implies that consumers will become informed. If insurers believe that consumers will remain uninformed, then a single policy, say C_μ, will be offered. But $I(C_\mu) \geq 0$, so consumers will become informed, and this cannot be an equilibrium. If insurers believe that consumers will become informed, then policies $\{C_A, C_B\}$ satisfying inequalities (20) and (21) will be offered. Since $I(C_A, C_B) \geq 0$, consumers will in fact choose to become informed and the insurer's beliefs will be verified in equilibrium.

Now consider the implications for a monopoly insurer facing a situation in which consumers may become informed regarding risk type prior to contracting. The insurer's maximization problem now can be written

[10] Note that, if $p_A'(e) = p_B'(e)$ and the self-selection constraint (21) separating the type Bs from the type As is binding, then $\hat{e}_{AA} = \hat{e}_{BA} = \hat{e}_{\mu A}$ and the value of information is $I(C_A, C_B) = 0$.

$$\max_{\alpha_d,\, \beta_d,\, \lambda_i,\, \gamma_{ij},\, \zeta_i} \sum_{i=A,B} q_i[(1-p_i(\hat{e}_i)\alpha_i - p_i(\hat{e}_i)\beta_i] \tag{24}$$

subject to the participation constraints

$$U_i(C_i, \hat{e}_i) - U_i(\mathbf{0}, \hat{e}_0) \geq 0, \quad i = A, B \tag{25}$$

with Lagrange multipliers λ_i, the self-selection constraints

$$U_i(C_i, \hat{e}_i) - U_i(C_j, \hat{e}_j) \geq 0, \quad i, j = A, B \tag{26}$$

with Lagrange multipliers γ_{ij}, and the effort level constraints

$$-p'_i(\hat{e}_i)[u(W_0 - \alpha_i) - u(W_0 - \ell + \beta_i)] - v'_i(\hat{e}_i) = 0 \tag{27}$$

$$-p'_i(\hat{e}_j)[u(W_0 - \alpha_j) - u(W_0 - \ell + \beta_j)] - v'_i(\hat{e}_j) = 0 \tag{28}$$

$$-p'_i(\hat{e}_0)[u(W_0) - u(W_0 - \ell)] - v'_i(\hat{e}_0) = 0, \quad i, j = A, B \tag{29}$$

with Lagrange multipliers ζ_{ij}. The Lagrangian and first-order conditions of this problem are presented in the Appendix.

If signaling costs are too high, insurer profits may be maximized by a single contract equilibrium in which the consumer surplus of type Bs is fully extracted, but type A individuals do not participate in the market. This equilibrium involves only the solution to the moral hazard problem for the type B consumers. Since this is a relatively uninteresting case, we assume that the insurer's profit maximizing solution involves participation by type A consumers. If so, the insurer then offers the menu of policies $\{C_{B*}, C_{A*}\}$ that satisfy

$$U_A(C_{A*}, \hat{e}_{A*}) - U_A(\mathbf{0}, \hat{e}_0) = 0, \tag{30}$$

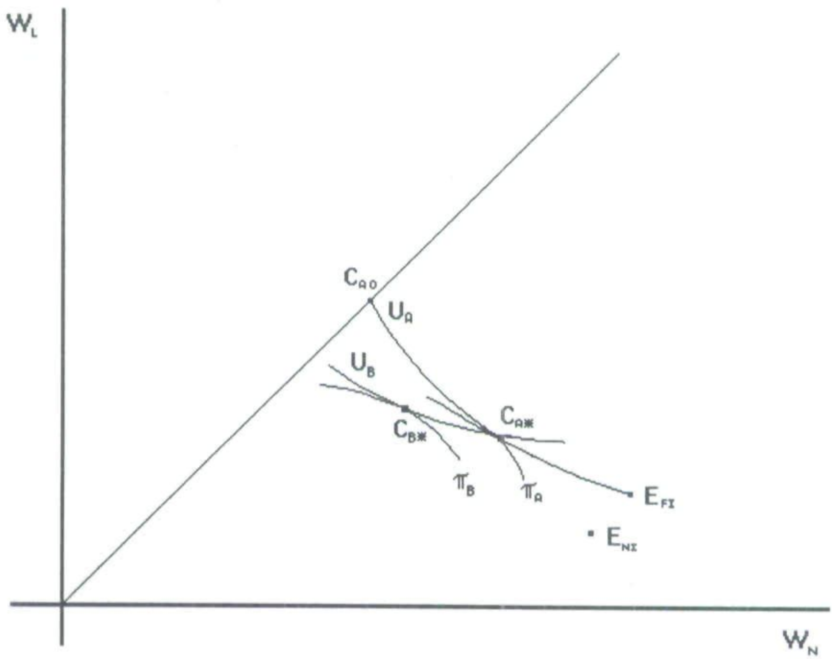
$$-p'_A(\hat{e}_A)[u(W_0 - \alpha_A) - u(W_0 - \ell + \beta_A)] - v'_A(\hat{e}_A) = 0, \tag{31}$$

$$U_B(C_{B*}, \hat{e}_{B*}) - U_B(C_{A*}, \hat{e}_{A*}) = 0, \tag{32}$$

$$-p'_B(\hat{e}_B)[u(W_0 - \alpha_B) - u(W_0 - \ell + \beta_B)] - v'_B(\hat{e}_B) = 0. \tag{33}$$

One possible separating equilibrium is shown in Figure 3. At contract C_{A*}, type A consumers exercise the desired effort level and are indifferent between C_{A*} and their endowment. The type A policyholders' surplus is fully extracted by the insurer. The variable effort indifference curves of type B consumers will have a flatter slope in state space than the type A variable effort indifference curve because the loss prevention activities of type Bs are not as productive as those of type A consumers and, hence, type Bs will be less willing to trade coverage for a lower premium (and higher effort level). For each particular candidate for C_{A*} (located along the type A variable effort indifference curve), there exists a type B variable effort indifference curve in state space through that point such that type Bs are indifferent between the set of contracts along this type B indifference curve and the candidate for C_{A*}. (That is, there is a type B variable effort indifference curve through each point on the type A variable effort indifference curve through the endowment.) The particular contracts designed by the insurer for types A and B will be the set of contracts (with C_{A*} along the type A variable effort indifference curve through the endowment and C_{B*} along the type B variable effort indifference curve through C_{A*}) that maximize the sum of insurer profits from both contracts. Note that nothing precludes the possibility that the profit maximizing set of contracts involves a single point in state space (i.e., $\{C_{B*}, C_{A*}\}$ involves a pool). The precise location of the equilibrium policies is affected by the same factors discussed in the pure moral hazard case with the modification that the relative productivity of self-protection and the actual number of consumers of each risk type become relevant. As in the post-contract information case, the positive value of information is reflected in Figure 3 by a shift in the endowment from E_{NI} to E_{FI}.

Figure 3
A Separating Equilibrium with Pre-Contract Information



Despite the change in contract offerings, the insurer is worse off than in the no information case. If policyholders become informed, then there are additional constraints upon the insurer's maximization problem. If any of the additional constraints bind (which, given positive effort levels, they must to separate the types), profits must fall. In the informed equilibrium, only type A individuals have their full surplus extracted. Type B individuals have only partial extraction. In the no information case, the insurer is able to fully extract all consumer surplus from all market participants. The insurer could attempt to increase overall consumer surplus to offset the partial extraction problem by attempting to make insurance more attractive to consumers, but this involves offering higher levels of coverage at the same price or the same levels of coverage at lower prices. The former is prohibited by the incentive compatibility constraints, and the latter is clearly not profit maximizing. Thus, the insurer will change its contract offerings from $\{C_{\mu *}\}$ to $\{C_{A*}, C_{B*}\}$ if it determines that the value of information to consumers is positive.

CONCLUSION

This study has shown that, in a relatively simple economic environment, a monopoly insurer can use price-quantity mechanisms to deal with moral hazard alone and with situations where both moral hazard and adverse selection are present in the market. The pure adverse selection model of Stiglitz (1977) obtains as a special case. With no information available about type, the only informational problem the insurer faces is moral hazard, which can be dealt with through partial coverage contracts that force the optimum choice of care level. In the case of post-contract information, information has positive value to consumers and negative value to the insurer because consumers' ability to adjust effort levels at the endowment increases their utility, and any policy inducing participation in the market must reflect this utility increase. Consumers also are better off and the insurer worse off in the presence of pre-contract information. In this case, consumers can use information to influence both contract choice and care levels. The additional constraints imposed upon the insurer by the adverse selection problem result in lower insurer profits and the retention of some consumer surplus by higher-risk consumers. In either case, the positive value of information to consumers is not dependent upon the monopoly market structure.

One policy implication of the results is that pooling of individuals by the insurer may increase the society's probability of loss when adverse selection and moral hazard are simultaneously present. Successful pools will likely occur only at lower effort levels (e.g., C_{d*} versus $C_{\mu *}$) than would be the case if only moral hazard or adverse selection is present in the market. Whenever the heterogeneity of the population is endogenous (because it is in part a function of moral hazard), attempts to pool the population at a price based on the loss prevention productivity of the average individual exacerbate the moral hazard problem. Failure to recognize this possibility may help explain why cost estimates of community rated social insurance programs frequently prove to be lower than the actual costs ultimately observed.

Clearly, much research remains to be done on the interaction of moral hazard and adverse selection. One obvious line of investigation would be to consider other possible structures for the interaction of adverse selection and moral hazard. In the case considered here, adverse selection arises in part because some individuals are more productive at loss prevention activity. This might be appropriate in markets such as automobile insurance, where drunks driving at high speeds are likely to have an accident independent of their innate driving ability, but driving ability may become more relevant to the probability of loss as greater care is exercised. One might consider the case where adverse selection is fully exogenous (e.g., genetic markers), but higher care levels might reduce differences in probability of loss. This formulation may be more appropriate for life (and possibly health) insurance, for example. Another line of inquiry is to consider the role of different objective functions. Can the social insurer, who pools for policy reasons, avoid the undesirable effort incentives observed here by altering its objective function? Analysis of the competitive case is more complex, but insights gained from the analysis of a single principal's mechanism design problem may be helpful in this area as well.

The first steps taken here suggest that understanding the interaction of moral hazard and adverse selection is clearly important to understanding the functioning of a number of real world markets. Just as markets with adverse selection or moral hazard alone behave differently than markets with symmetric information, markets with adverse selection and moral hazard simultaneously present behave differently than markets where either is present alone.

APPENDIX

No Information Case

The Lagrangian for the no information case is

$$\begin{aligned}\mathcal{L} = {} & q[(1 - p_\mu(\hat{e}_\mu))\alpha_\mu - p_\mu(\hat{e}_\mu)\beta_\mu] \\ & + \lambda_\mu[p_\mu(\hat{e}_\mu)u(W_0 - \ell + \beta_\mu) + (1-p_\mu(\hat{e}_\mu))u(W_0-\alpha_\mu) - v_\mu(\hat{e}_\mu) - p_\mu(\hat{e}_0)u(W_0-\ell) \\ & - (1-p_\mu(\hat{e}_0))u(W_0) + v_\mu(\hat{e}_0)] \\ & - \zeta_\mu\{p'_\mu(\hat{e}_\mu)[u(W_0-\alpha_\mu) - u(W_0 - \ell + \beta_\mu)] + v'_\mu(\hat{e}_\mu)\} - \zeta_0\{p'_\mu(\hat{e}_0)[u(W_0) \\ & - u(W_0 - \ell)] + v'_\mu(\hat{e}_0)\}.\end{aligned}$$

The first-order conditions for the no information case are

$$\begin{aligned}\partial\mathcal{L}/\partial\alpha_\mu = {} & q(1 - p_\mu(\hat{e}_\mu)) - \lambda_\mu(1 - p_\mu(\hat{e}_\mu))u'(W_0 - \alpha_\mu) + \zeta_\mu p'_\mu(\hat{e}_\mu)u'(W_0 - \alpha_\mu) \\ & - q[p'_\mu(\hat{e}_\mu)(\partial\hat{e}_\mu/\partial\alpha_\mu)][\alpha_\mu+\beta_\mu] \\ & + \lambda_\mu\{[p'_\mu(\hat{e}_\mu)(\partial\hat{e}_\mu/\partial\alpha_\mu)][u(W_0 - \ell + \beta_\mu) - u(W_0-\alpha_\mu)] - [v'_\mu(\hat{e}_\mu)(\partial\hat{e}_\mu/\partial\alpha_\mu)]\} \\ & - \zeta_\mu\{[p''_\mu(\hat{e}_\mu)(\partial\hat{e}_\mu/\partial\alpha_\mu)][u(W_0-\alpha_\mu) - u(W_0 - \ell + \beta_\mu)] + [v''_\mu(\hat{e}_\mu)(\partial\hat{e}_\mu/\partial\alpha_\mu)]\} \leq 0\end{aligned}$$

$$\alpha_\mu \geq 0 \quad \alpha_\mu(\partial\mathcal{L}/\partial\alpha_\mu) = 0$$

$$\partial \mathcal{L}/\partial\beta_\mu = -q[p_\mu(\hat{e}_\mu)] + \lambda_\mu p_\mu(\hat{e}_\mu)u'(W_0 - \ell + \beta_\mu) + \zeta_\mu p'_\mu(\hat{e}_\mu)u'(W_0 - \ell + \beta_\mu)$$
$$- q[p'_\mu(\hat{e}_\mu)(\partial\hat{e}_\mu/\partial\beta_\mu)][\beta_\mu + \alpha_\mu]$$

$$+ \lambda_\mu\{[p'_\mu(\hat{e}_\mu)(\partial\hat{e}_\mu/\partial\beta_\mu)][u(W_0 - \ell + \beta_\mu) - u(W_0 - \alpha_\mu)] - [v'_\mu(\hat{e}_\mu)(\partial\hat{e}_\mu/\partial\beta_\mu)]\}$$

$$- \zeta_\mu\{[(p''_\mu(\hat{e}_\mu)(\partial\hat{e}_\mu/\partial\beta_\mu)][u(W_0 - \alpha_\mu) - u(W_0 - \ell + \beta_\mu)] + [v''_\mu(\hat{e}_\mu)(\partial\hat{e}_\mu/\partial\beta_\mu)]\} \le 0$$

$$\beta_\mu \ge 0 \quad \beta_\mu(\partial \mathcal{L}/\partial\beta_\mu) = 0$$

$$\partial \mathcal{L}/\partial\lambda_\mu = p_\mu(\hat{e}_\mu)u(W_0 - \ell + \beta_\mu) + (1 - p_\mu(\hat{e}_\mu))u(W_0 - \alpha_\mu) - v_\mu(\hat{e}_\mu)$$

$$- p_\mu(\hat{e}_0)u(W_0 - \ell) - (1 - p_\mu(\hat{e}_0))u(W_0) + v_\mu(\hat{e}_0) \ge 0 \qquad \lambda_\mu \ge 0 \quad \lambda_\mu(\partial \mathcal{L}/\partial\lambda_\mu) = 0$$

$$\partial \mathcal{L}/\partial\zeta_\mu = -p'_\mu(\hat{e}_\mu)[u(W_0 - \alpha_\mu) - u(W_0 - \ell + \beta_\mu)] - v'_\mu(\hat{e}_\mu) = 0$$

$$\partial \mathcal{L}/\partial\zeta_0 = -p'_\mu(\hat{e}_0)[u(W_0) - u(W_0 - \ell)] - v'_\mu(\hat{e}_0) = 0.$$

Post-Contract Information Case

The Lagrangian for the post-contract information case is

$$\mathcal{L} = q_A[(1 - p_A(\hat{e}_d))\alpha_d - p_A(\hat{e}_d)\beta_d] + q_B[(1 - p_B(\hat{e}_d))\alpha_d - p_B(\hat{e}_d)\beta_d]$$

$$+ \lambda_A[p_A(\hat{e}_d)u(W_0 - \ell + \beta_d) + (1 - p_A(\hat{e}_d))u(W_0 - \alpha_d) - v_A(\hat{e}_d) - p_A(\hat{e}_0)u(W_0 - \ell)$$
$$- (1 - p_A(\hat{e}_0))u(W_0) + v_A(\hat{e}_0)]$$

$$+ \lambda_B[p_B(\hat{e}_d)u(W_0 - \ell + \beta_d) + (1 - p_B(\hat{e}_d))u(W_0 - \alpha_d) - v_B(\hat{e}_d) - p_B(\hat{e}_0)u(W_0 - \ell)$$
$$- (1 - p_B(\hat{e}_0))u(W_0) + v_B(\hat{e}_0)]$$

$$- \zeta_{Ad}\{p'_A(\hat{e}_d)[u(W_0 - \alpha_d) - u(W_0 - \ell + \beta_d)] + v'_A(\hat{e}_d)\}$$

$$- \zeta_{Bd}\{p'_B(\hat{e}_d)[u(W_0 - \alpha_d) - u(W_0 - \ell + \beta_d)] + v'_B(\hat{e}_d)\}$$

$$- \zeta_{A0}\{p'_A(\hat{e}_0)[u(W_0) - u(W_0 - \ell)] + v'_A(\hat{e}_0)\}$$

$$- \zeta_{B0}\{p'_B(\hat{e}_0)[u(W_0) - u(W_0 - \ell)] + v'_B(\hat{e}_0)\}.$$

The first-order conditions for the post-contract information case are

$$\partial \mathcal{L}/\partial\alpha_d = q_A(1 - p_A(\hat{e}_d)) + q_B(1 - p_B(\hat{e}_d)) - \lambda_A[(1 - p_A(\hat{e}_d))u'(W_0 - \alpha_d)]$$
$$- \lambda_B[(1 - p_B(\hat{e}_d))u'(W_0 - \alpha_d)]$$

$$+ \zeta_{Ad}\, p'_A(\hat{e}_d)u'(W_0 - \alpha_d) + \zeta_{Bd} p'_B(\hat{e}_d)u(W_0 - \alpha_d)$$

$$-q_A[p'_A(\hat{e}_d)(\partial\hat{e}_d/\partial\alpha_d)][\alpha_d + \beta_d] - q_B[p'_B(\hat{e}_d)(\partial\hat{e}_d/\partial\alpha_d)][\alpha_d + \beta_d]$$

$$+ \lambda_A\{[p'_A(\hat{e}_d)(\partial\hat{e}_d/\partial\alpha_d)][u(W_0 - \ell + \beta_d) - u(W_0-\alpha_d)] - [v'_A(\hat{e}_d)(\partial\hat{e}_d/\partial\alpha_d)]\}$$

$$- \zeta_{Ad}\{[p''_A(\hat{e}_d)(\partial\hat{e}_d/\partial\alpha_d)][u(W_0-\alpha_d) - u(W_0 - \ell +\beta_d)] + [v''_A(\hat{e}_d)(\partial\hat{e}_d/\partial\alpha_d)]\}$$

$$- \zeta_{Bd}\{[p''_B(\hat{e}_d)(\partial\hat{e}_d/\partial\alpha_d)][u(W_0-\alpha_d) - u(W_0- \ell + \beta_d)] + [v''_B(\hat{e}_d)(\partial\hat{e}_d/\partial\alpha_d)]\} \leq 0$$

$$\alpha_d \geq 0 \quad \alpha_d(\partial\mathcal{L}/\partial\alpha_d) = 0$$

$$\partial\mathcal{L}/\partial\beta_d = -q_A[p_A(\hat{e}_d)] - q_B[p_B(\hat{e}_d)] + \lambda_A p_A(\hat{e}_d)u'(W_0- \ell +\beta_d) + \lambda_B p_B(\hat{e}_d)u'(W_0- \ell +\beta_d)$$

$$+ \zeta_{Ad}\, p'_A(\hat{e}_d)u'(W_0 - \ell + \beta_d) + \zeta_{Bd}\, p'_B(\hat{e}_d)u'(W_0 - \ell + \beta_d)$$

$$- q_A[p'_A(\hat{e}_d)(\partial\hat{e}_d/\partial\beta_d)][\beta_d + \alpha_d] - q_B[p'_B(\hat{e}_d)(\partial\hat{e}_d/\partial\beta_d)][\beta_d + \alpha_d]$$

$$+ \lambda_A\{[p'_A(\hat{e}_d)(\partial\hat{e}_d/\partial\beta_d)][u(W_0-\ell+\beta_d) - u(W_0 - \alpha_d)] - [v'_A(\hat{e}_d)(\partial\hat{e}_d/\partial\beta_d)]\}$$

$$- \zeta_{Ad}\{[p''_A(\hat{e}_d)(\partial\hat{e}_d/\partial\beta_d)][u(W_0-\alpha_d) - u(W_0-\ell+\beta_d)] + [v''_A(\hat{e}_d)(\partial\hat{e}_d/\partial\beta_d)]\}$$

$$- \zeta_{Bd}\{[p''_B(\hat{e}_d)(\partial\hat{e}_d/\partial\beta_d)][u(W_0-\alpha_d) - u(W_0-\ell+\beta_d)] + [v''_B(\hat{e}_d)(\partial\hat{e}_d/\partial\beta_d)]\} \leq 0$$

$$\beta_d \geq 0 \quad \beta_d(\partial\mathcal{L}/\partial\beta_d) = 0$$

$$\partial\mathcal{L}/\partial\lambda_A = p_A(\hat{e}_d)u(W_0-\ell+\beta_d) + (1-p_A(\hat{e}_d))u(W_0-\alpha_d) - v_A(\hat{e}_d)$$

$$- p_A(\hat{e}_0)u(W_0-\ell) - (1-p_A(\hat{e}_0))u(W_0) + v_A(\hat{e}_0) \geq 0 \quad \lambda_A \geq 0 \quad \lambda_A(\partial\mathcal{L}/\partial\lambda_A) = 0$$

$$\partial\mathcal{L}/\partial\lambda_B = p_B(\hat{e}_d)u(W_0 - \ell + \beta_d) + (1 - p_B(\hat{e}_d))u(W_0 - \alpha_d) - v_A(\hat{e}_d)$$

$$- p_B(\hat{e}_0)u(W_0-\ell) - (1-p_B(\hat{e}_0))\, u(W_0) + v_B(\hat{e}_0) \geq 0 \quad \lambda_B \geq 0 \quad \lambda_B(\partial\mathcal{L}/\partial\lambda_B) = 0$$

$$\partial\mathcal{L}/\partial\zeta_{Ad} = -p'_A(\hat{e}_d)[u(W_0 - \alpha_d) - u(W_0 - \ell + \beta_d)] - v'_A(e_d) = 0$$

$$\partial\mathcal{L}/\partial\zeta_{Bd} = -p'_B(\hat{e}_d)[u(W_0 - \alpha_d) - u(W_0 - \ell + \beta_d)] - v'_B(e_d) = 0$$

$$\partial\mathcal{L}/\partial\zeta_{A0} = -p'_A(\hat{e}_0)[u(W_0) - u(W_0 - \ell)] - v'_A(\hat{e}_0)\} = 0$$

$$\partial\mathcal{L}/\partial\zeta_{B0} = -p'_B(\hat{e}_0)[u(W_0) - u(W_0 - \ell)] - v'_B(\hat{e}_0)\} = 0.$$

Pre-Contract Information Case

The Lagrangian for the pre-contract information case is

$$\mathcal{L} = q_A[(1 - p_A(\hat{e}_A))\alpha_A - p_A(\hat{e}_A)\beta_A] + q_B[(1 - p_B(\hat{e}_B))\alpha_B - p_B(\hat{e}_B)\, \beta_B]$$

$$+ \lambda_A[p_A(\hat{e}_A)u(W_0-\ell+\beta_A) + (1-p_A(\hat{e}_A))u(W_0-\alpha_A) - v_A(\hat{e}_A) - p_A(\hat{e}_0)u(W_0-\ell)$$

$$- (1-p_A(\hat{e}_0))u(W_0) + v_A(\hat{e}_0)]$$

$$+ \lambda_B[p_B(\hat{e}_B)u(W_0-\ell+\beta_B) + (1-p_B(\hat{e}_B))u(W_0-\alpha_B) - v_B(\hat{e}_B) - p_B(\hat{e}_0)u(W_0-\ell)$$
$$- (1-p_B(\hat{e}_0))u(W_0) + v_B(\hat{e}_0)]$$

$$+ \gamma_{AB}[p_A(\hat{e}_A)u(W_0 - \ell + \beta_A) + (1 - p_A(\hat{e}_A))u(W_0 - \alpha_A) - v_A(\hat{e}_A)$$
$$- p_A(\hat{e}_B)u(W_0 - \ell + \beta_B) - (1 - p_A(\hat{e}_B))u(W_0 - \alpha_B) + v_A(\hat{e}_B)]$$

$$+ \gamma_{BA}[p_B(\hat{e}_B)u(W_0 - \ell + \beta_B) + (1 - p_B(\hat{e}_B))u(W_0 - \alpha_B) - v_B(\hat{e}_B)$$
$$- p_B(\hat{e}_A)u(W_0 - \ell + \beta_A) - (1 - p_B(\hat{e}_A))u(W_0 - \alpha_A) + v_B(\hat{e}_A)]$$

$$- \zeta_{AA}\{p'_A(\hat{e}_A)[u(W_0 - \alpha_A) - u(W_0 - \ell + \beta_A)] + v'_A(\hat{e}_A)\}$$

$$- \zeta_{AB}\{p'_A(\hat{e}_B)[u(W_0 - \alpha_B) - u(W_0 - \ell + \beta_B)] + v'_A(\hat{e}_B)\}$$

$$- \zeta_{BB}\{p'_B(\hat{e}_B)[u(W_0 - \alpha_B) - u(W_0 - \ell + \beta_B)] + v'_B(\hat{e}_B)\}$$

$$- \zeta_{BA}\ \{p'_B(\hat{e}_A)[u(W_0 - \alpha_A) - u(W_0 - \ell + \beta_A)] + v'_B(\hat{e}_A)\}$$

$$- \zeta_{A0}\{p'_A(\hat{e}_0)[u(W_0) - u(W_0 - \ell)] + v'_A(\hat{e}_0)\}$$

$$- \zeta_{B0}\{p'_B(\hat{e}_0)[u(W_0) - u(W_0 - \ell)] + v'_B(\hat{e}_0)\}.$$

The first-order conditions for the pre-contract information case are

$$\partial\mathcal{L}/\partial\alpha_A = q_A(1-p_A(\hat{e}_A)) - \lambda_A[(1-p_A(\hat{e}_A))u'(W_0 - \alpha_A)] - \gamma_{AB}(1 - p_A(\hat{e}_A))u'(W_0 - \alpha_A)$$

$$+ \gamma_{BA}(1-p_B(\hat{e}_A))u'(W_0-\alpha_A) + \zeta_{AA}\, p'_A(\hat{e}_A)u'(W_0-\alpha_A) + \zeta_{BA}\, p'_B(\hat{e}_A)u'(W_0-\alpha_A)$$

$$- q_A[p'_A(\hat{e}_A)(\partial\hat{e}_A/\partial\alpha_A)][\alpha_A + \beta_A]$$

$$+ \lambda_A\{[p'_A(\hat{e}_A)(\partial\hat{e}_A/\partial\alpha_A)][u(W_0-\ell+\beta_A) - u(W_0-\alpha_A)] - [v'_A(\hat{e}_A)(\partial\hat{e}_\mu/\partial\alpha_A)]\}$$

$$+ \gamma_{AB}\{[p'_A(\hat{e}_A)(\partial\hat{e}_A/\partial\alpha_A)][u(W_0-\ell+\beta_A) - u(W_0-\alpha_A)] - [v'_A(\hat{e}_A)(\partial\hat{e}_A/\partial\alpha_A)]\}$$

$$- \gamma_{BA}\{[p'_B(\hat{e}_A)(\partial\hat{e}_A/\partial\alpha_A)][u(W_0-\ell+\beta_A) - u(W_0-\alpha_A)] - [v'_B(\hat{e}_A)(\partial\, \hat{e}_A/\partial\alpha_A)]\}$$

$$- \zeta_{AA}\{[p''_A(\hat{e}_A)(\partial\hat{e}_A/\partial\alpha_A)][u(W_0-\alpha_A) - (W_0-\ell+\beta_A)] + [v''_A(\hat{e}_A)(\partial\hat{e}_A/\partial\alpha_A)]\}$$

$$- \zeta_{BA}\{p''_B(\hat{e}_A)(\partial\hat{e}_A/\partial\alpha_A)][u(W_0-\alpha_A)- u(W_0-\ell+\beta_A)] + [v''_B(\hat{e}_A)(\partial\hat{e}_A/\partial\alpha_A)]\} \leq 0$$

$$\alpha_A \geq 0 \quad \alpha_A(\partial\mathcal{L}/\partial\alpha_A) = 0$$

$$\partial\mathcal{L}/\partial\beta_A = -q_A[p_A(\hat{e}_A)] + \lambda_A p_A(\hat{e}_A)u'(W_0 - \ell + \beta_A) + \gamma_{AB} p_A(\hat{e}_A))u'(W_0 - \ell + \beta_A)$$

$$- \gamma_{BA} p_B(\hat{e}_A))u'(W_0 - \ell + \beta_A) + \zeta_{AA}\, p'_A(\hat{e}_A)u'(W_0 - \ell + \beta_A)$$
$$+ \zeta_{BA}\, p'_B(\hat{e}_A)u'(W_0 - \ell + \beta_A)$$

$$- q_A[p'_A(\hat{e}_A)(\partial\hat{e}_A/\partial\beta_A)][\beta_A + \alpha_A]$$

$$+ \lambda_A\{[p'_A(\hat{e}_A)(\partial\hat{e}_A/\partial\beta_A)][u(W_0-\ell+\beta_A) - u(W_0-\alpha_A)] - [v'_A(\hat{e}_A)(\partial\hat{e}_A/\partial\beta_A)]\}$$

$$+ \gamma_{AB}\{[p'_A(\hat{e}_A)(\partial\hat{e}_A/\partial\beta_A)][u(W_0-\ell+\beta_A) - u(W_0-\alpha_A)] - [v'_A(\hat{e}_A)(\partial\hat{e}_A/\partial\beta_A)]\}$$

$$- \gamma_{BA}\{[p'_B(\hat{e}_A)(\partial\hat{e}_A/\partial\beta_A)][u(W_0-\ell+\beta_A) - u(W_0-\alpha_A)] - [v'_B(\hat{e}_A)(\partial\hat{e}_\mu/\partial\beta_A)]\}$$

$$- \zeta_{AA}\{[p''_A(\hat{e}_A)(\partial\hat{e}_A/\partial\beta_A)][u(W_0-\alpha_A) - u(W_0-\ell+\beta_A)] + [v''_A(\hat{e}_A)(\partial\hat{e}_\mu/\partial\beta_A)]\}$$

$$- \zeta_{BA}\{[p''_B(\hat{e}_A)(\partial\hat{e}_A/\partial\beta_A)][u(W_0-\alpha_A)- u(W_0-\ell+\beta_A)] + [v''_B(\hat{e}_A)(\partial\hat{e}_\mu/\partial\beta_A)]\} \le 0$$

$$\beta_A \ge 0 \qquad \beta_A(\partial\mathcal{L}/\partial\beta_A) = 0$$

$$\partial\mathcal{L}/\partial\alpha_B = q_B(1-p_B(\hat{e}_B)) - \lambda_B[(1 - p_B(\hat{e}_B))u'(W_0 - \alpha_B)] - \gamma_{BA}(1 - p_B(\hat{e}_B))u'(W_0 - \alpha_B)$$

$$+ \gamma_{AB}(1-p_A(\hat{e}_B))u'(W_0-\alpha_B) + \zeta_{BB}\, p'_B(\hat{e}_B)u'(W_0- \alpha_B) + \zeta_{AB}\, p'_A(\hat{e}_B)u'(W_0-\alpha_B)$$

$$- q_B[p'_B(\hat{e}_B)(\partial\hat{e}_B/\partial\alpha_B)[\alpha_B + \beta_B]$$

$$+ \lambda_B\{[p'_B(\hat{e}_B)(\partial\hat{e}_B/\partial\alpha_B)][u(W_0-\ell+\beta_B) - u(W_0-\alpha_B)] - [v'_B(\hat{e}_B)(\partial\hat{e}_B/\partial\alpha_B)]\}$$

$$+ \gamma_{BA}\{[p'_B(\hat{e}_B)(\partial\hat{e}_B/\partial\alpha_B)[u(W_0-\ell+\beta_B) - u(W_0-\alpha_B)] - [v'_B(\hat{e}_B)(\partial\hat{e}_B/\partial\alpha_B)]\}$$

$$- \gamma_{AB}\{[p'_A(\hat{e}_B)(\partial\hat{e}_B/\partial\alpha_B)][u(W_0-\ell+\beta_B) - u(W_0-\alpha_B)] - [v'_A(\hat{e}_B)(\partial\hat{e}_B/\partial\alpha_B)]\}$$

$$- \zeta_{BB}\{[p''_B(\hat{e}_B)(\partial\hat{e}_B/\partial\alpha_B)][u(W_0-\alpha_B) - u(W_0-\ell+\beta_B)] + [v''_B(\hat{e}_B)(\partial\hat{e}_B/\partial\alpha_B)]\}$$

$$- \zeta_{AB}\{[p''_A(\hat{e}_B)(\partial\hat{e}_B/\partial\alpha_B)][u(W_0-\alpha_B)- u(W_0-\ell+\beta_B)] + [v''_A(\hat{e}_B)(\partial\hat{e}_B/\partial\alpha_B)]\} \le 0$$

$$\alpha_B \ge 0 \qquad \alpha_B(\partial\mathcal{L}/\partial\alpha_B) = 0$$

$$\partial\mathcal{L}/\partial\beta_B = -q_B[p_B(\hat{e}_B)] + \lambda_B p_B(\hat{e}_B)u'(W_0 - \ell + \beta_B) + \gamma_{BA} p_B(\hat{e}_B))u'(W_0 - \ell + \beta_B)$$

$$- \gamma_{AB} p_A(\hat{e}_B))u'(W_0-\ell+\beta_B) + \zeta_{BB}\, p'_B(\hat{e}_B)u'(W_0-\ell+\beta_B) + \zeta_{AB} p'_A(\hat{e}_B)u'(W_0-\ell+\beta_B)$$

$$- q_B[p'_B(\hat{e}_B)(\partial\hat{e}_B/\partial\beta_B)[\beta_B + \alpha_B]$$

$$+ \lambda_B\{[p'_B(\hat{e}_B)(\partial\hat{e}_B/\partial\beta_B)][u(W_0-\ell+\beta_B) - u(W_0 - \alpha_B)] - [v'_B(\hat{e}_B)(\partial\hat{e}_B/\partial\beta_B)]\}$$

$$+ \gamma_{BA}\{[p'_B(\hat{e}_B)(\partial\hat{e}_B/\partial\beta_B)][u(W_0-\ell+\beta_B) - u(W_0-\alpha_B)] - [v'_B(\hat{e}_B)(\partial\hat{e}_B/\partial\beta_B)]\}$$

$$- \gamma_{AB}\{[p'_A(\hat{e}_B)(\partial\hat{e}_B/\partial\beta_B)][u(W_0-\ell+\beta_B) - u(W_0-\alpha_B)] - [v'_A(\hat{e}_B)(\partial\hat{e}_B/\partial\beta_B)]\}$$

$$- \zeta_{BB}\{[p''_B(\hat{e}_B)(\partial\hat{e}_B/\partial\beta_B)][u(W_0-\alpha_B) - u(W_0-\ell+\beta_B)] + [v''_B(\hat{e}_B)(\partial\hat{e}_B/\partial\beta_B)]\}$$

$$- \zeta_{AB}\{[p''_A(\hat{e}_B)(\partial\hat{e}_B/\partial\beta_B)][u(W_0-\alpha_B)- u(W_0-\ell+\beta_B)] + [v''_A(\hat{e}_B)(\partial\hat{e}_B/\partial\beta_B)]\} \leq 0$$

$$\beta_B \geq 0 \qquad \beta_B(\partial\mathcal{L}/\partial\beta_B) = 0$$

$$\partial\mathcal{L}/\partial\lambda_A = p_A(\hat{e}_A)u(W_0 - \ell + \beta_A) + (1 - p_A(\hat{e}_A))u(W_0 - \alpha_A) - v_A(\hat{e}_A)$$

$$- p_A(\hat{e}_0)u(W_0-\ell) - (1-p_A(\hat{e}_0))u(W_0) + v_A(\hat{e}_0) \geq 0 \quad \lambda_A \geq 0 \quad \lambda_A(\partial\mathcal{L}/\partial\lambda_A) = 0$$

$$\partial\mathcal{L}/\partial\lambda_B = p_B(\hat{e}_B)u(W_0 - \ell + \beta_B) + (1 - p_B(\hat{e}_B))u(W_0 - \alpha_B) - v_A(\hat{e}_B)$$

$$- p_B(\hat{e}_0)u(W_0-\ell) - (1-p_B(\hat{e}_0))u(W_0) + v_B(\hat{e}_0) \geq 0 \quad \lambda_B \geq 0 \quad \lambda_B(\partial\mathcal{L}/\partial\lambda_B) = 0$$

$$\partial\mathcal{L}/\partial\gamma_{AB} = p_A(\hat{e}_A)u(W_0 - \ell + \beta_A) + (1 - p_A(\hat{e}_A))u(W_0 - \alpha_A) - v_A(\hat{e}_A)$$

$$- p_A(\hat{e}_B)u(W_0-\ell+\beta_B) - (1-p_A(\hat{e}_B))u(W_0-\alpha_B) + v_A(\hat{e}_B) \geq 0$$
$$\gamma_{AB} \geq 0 \quad \gamma_{AB}(\partial\mathcal{L}/\partial\gamma_{AB}) = 0$$

$$\partial\mathcal{L}/\partial\gamma_{BA} = p_B(\hat{e}_B)u(W_0 - \ell + \beta_B) + (1 - p_B(\hat{e}_B))u(W_0 - \alpha_B) - v_B(\hat{e}_B)$$

$$- p_B(\hat{e}_A)u(W_0-\ell+\beta_A) - (1-p_B(\hat{e}_A))u(W_0-\alpha_A) + v_B(\hat{e}_A) \geq 0$$
$$\gamma_{BA} \geq 0 \quad \gamma_{BA}(\partial\mathcal{L}/\partial\gamma_{BA}) = 0$$

$$\partial\mathcal{L}/\partial\zeta_{AA} = -p'_A(\hat{e}_A)[u(W_0 - \alpha_A) - u(W_0 - \ell + \beta_A)] - v'_A(\hat{e}_A) = 0$$

$$\partial\mathcal{L}/\partial\zeta_{AB} = -p'_A(\hat{e}_B)[u(W_0 - \alpha_B) - u(W_0 - \ell + \beta_B)] - v'_A(\hat{e}_B) = 0$$

$$\partial\mathcal{L}/\partial\zeta_{BB} = -p'_B(\hat{e}_B)[u(W_0 - \alpha_B) - u(W_0 - \ell + \beta_B)] - v'_B(\hat{e}_B) = 0$$

$$\partial\mathcal{L}/\partial\zeta_{BA} = -p'_B(\hat{e}_A)[u(W_0 - \alpha_A) - u(W_0 - \ell + \beta_A)] - v'_B(\hat{e}_A) = 0$$

$$\partial\mathcal{L}/\partial\zeta_{A0} = -p'_A(\hat{e}_0)[u(W_0) - u(W_0 - \ell)] - v'_A(\hat{e}_0) = 0$$

$$\partial\mathcal{L}/\partial\zeta_{B0} = -p'_B(\hat{e}_0)[u(W_0) - u(W_0 - \ell)] - v'_B(\hat{e}_0) = 0.$$

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