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The Joint Demand for Health Insurance and Preventive Medicine

1. INTRODUCTION

In this paper we investigate the nature and properties of the joint demand for health insurance and preventive medicine. Our decision-maker is a globally risk-averse person whose welfare depends on his consumption and health. The decision horizon spans two periods, the present and the future. Present income and health are assumed to be given, but future income is uncertain because it depends on an uncertain future state of health. We suppose that the individual can manage this uncertainty in two

This paper represents an amalgamation of two earlier papers: "A Model of Demand for Preventive Medicine under Uncertainty," by Nordquist, and "The Consumer's Demand for Medical Goods and Services," by Wu. We wish to thank the conference participants, and especially R. Berg, M. Grossman, and S. Rosen, for many helpful comments. Notes 1, 4, and 7 have been added in partial response. We are indebted to our colleagues, M. Balch, J. Jeffers, and J. Heckman, for their help on earlier drafts. Of course, we alone assume responsibility for any shortcomings that may remain.

ways: (1) by purchasing an insurance policy that promises benefits (money payoffs) contingent on his future state of health, and (2) by choosing a bundle of medical goods and services called preventive medicine that promises to influence his future health prospect. Preventive medicine, unlike ordinary consumption, has little or no direct effect on utility; its value arises mostly from the beneficial changes it produces in the consumer's health prospect. We recognize, however, that many ordinary consumer goods play a dual role: They not only yield utility directly but also influence the health prospect. Although the main portion of this paper is devoted to what might be appropriately called "the pure aspects of insurance and prevention," the effect of including goods that play a dual role is examined in a separate section. Regardless of these variations, our basic premise is that the consumer will choose present outlays on health insurance and preventive medicine so as to maximize expected utility.[1]

Notice that insurance and prevention are alternative but fundamentally different approaches to planning for future health and welfare. Barring moral hazard of one kind or another, health insurance permits a person to alter the *payoffs* of a random experiment in which poor health is a possibility without affecting its probability. More specifically, the market insurance enables the consumer to *redistribute* his wealth from the present to the more hazardous, uncertain future. Prevention, on the other hand, alters the prospect for future health without changing the payoffs (except inasmuch as prevention may not be a free good).[2]

In an uncertain setting there are two ways to characterize the individual's preferences for present and future consumption. First, we might suppose that they are essentially unaffected by his state of health, in which case we characterize the individual's expected utility in the framework of von Neumann-Morgenstern. Symbolically,

$$Eu = \int_0^1 u(C_1, c_2)dF(h;\cdot)$$

where u is a von Neumann-Morgenstern utility index; C_1 and c_2, respectively, are the levels of present and future consumption; $h \epsilon (0,1)$ is the state of health; and F is the probability distribution function of h. Alternatively, we might insist that health has a conditional influence on consumer preferences—that the health state should really be an explicit argument in the utility function. In this case we describe the individual's expected utility in the framework of what some have characterized as conditional expected utility (Balch and Fishburn, 1974) and others, as the state-dependent approach to expected utility (Arrow, 1973). This expected utility is symbolically represented by

$$Eu^* = \int_0^1 u^*(C_1, c_2, h) dF(h; \cdot)$$

where u^* is a state-dependent utility index. Notice that in both of these expected utility formulations the probability distributions of h depend on various parameters. The analyses based on these alternative approaches are somewhat different and both require lengthy developments. Owing to limitation of space, we will restrict our analysis in this paper to the von Neumann-Morgenstern formulation.[3]

Now let us turn our attention to the constraints. First, define a health insurance policy by the pair $[I, x(h)I]$, where I is the stated premium, and $x(h)I$ is the total future payoff or benefit. Moreover, let ρI, $0 \leq \rho \leq 1$, be the private cost of insurance to the individual. The difference $(1 - \rho)I$ is the contribution of some third party such as employer or government. The consumer's present consumption, C_1, depends on his current income, Y_1, and current outlays for health insurance, ρI, preventive medicine, Z, and saving, S; i.e.,

$$C_1 = Y_1 - \rho I - Z - S$$

Future consumption, c_2, depends on future income, y_2; a schedule of health insurance payoffs, x; and the gross yield on savings, rS. Both y_2 and x are functions of the future random health state h and are therefore uncertain;[4] hence,

$$c_2(h) = y_2(h) + x(h)I + rS$$

Of course, the gross yield on savings may also be taken as random.

In the following development, we suppose that ordinary saving is identically equal to zero. Although the formal inclusion of saving presents little difficulty in either the specification or the solution of our problem, it does complicate the presentation. Furthermore, upon reflection one sees that saving and insurance are alike in that they both involve an intertemporal redistribution of income—insurance can be regarded as saving for specific future contingencies. The difference, of course, is that the yield on savings is not likely to be closely related to the state of health. In any case, we feel that the roles played by insurance and saving are sufficiently similar so that the exclusion of saving does not significantly weaken our solution.

Formally the consumer's choice problem now becomes

(1) $$\underset{I,Z}{\text{Maximize}} \quad Eu = \int_0^1 u(C_1, c_2) dF(h; \cdot)$$

(2) subject to $C_1 = Y_1 - \rho I - Z$

(3) $c_2 = y_2(h) + x(h)I$

where u is a von Neumann-Morgenstern utility index. We assume that the utility function possesses continuous first-, second-, and third-order derivatives.

We think that this model is of interest not only because of its bearing on the demand for health insurance and medical services but also because it represents a generalization of recent literature on the question of the optimal saving decision under uncertainty. Leland (1966) has analyzed precautionary saving when future income is uncertain. Sandmo (1969) has examined the case wherein the yield on saving is uncertain. In our model not only are both future income and the return on saving (or to be exact, the payoff from insurance) taken as random but we also permit the consumer to influence the distribution function of the random variable.[5]

This paper is divided into five sections. Section 2 introduces and defines three important concepts in our study. Section 3 develops the basic model in which the distribution of future health is assumed to depend on (1) the consumer's present outlay for prevention, and (2) an exogenous index of the future health environment. Section 4 extends the analysis to the case in which the distribution also depends on present consumption. Finally, in Section 5 we summarize our findings and suggest some policy implications. The proofs of various propositions have been placed in the Appendix to relieve the text of any cumbersomeness.

2. THREE RELEVANT CONCEPTS

In recent years there have been rather rapid advancements in theoretical concepts dealing with problems related to the economics of uncertainty. The concepts of stochastic dominance, risk aversion, and moral hazard play important roles in this paper. A brief specification of each of these concepts follows.

Stochastic Dominance

Stochastic dominance is a set of rules for ordering risky prospects (Hadar and Russell, 1971). Since we are dealing with a risk-averse consumer, it is appropriate to assume that prospects are ordered by second-degree stochastic dominance, denoted by $\mathcal{D}$.

Definition 1. Let $F(\theta)$ and $G(\theta)$ be two distinct probability distributions of the random variable θ, where $\theta \epsilon (0,1)$. Then $G \mathcal{D} F$ if and only if

$$\int_0^h G(\theta)d\theta \leq \int_0^h F(\theta)d\theta, \text{ for all } h \epsilon (0,1)$$

Now let $F(\theta,x)$ be the distribution function of the random variable θ, where x is a vector of shift parameters. ($F(\theta,x^0)$ is a given prospect of θ.) Assume that F_i and F_{ij} exist for all x_i and x_j and that they are continuous. Let h denote the health index, where $h \epsilon (0,1)$.

Definition 2. Let

$$R(h,x) = \int_0^h F(\theta,x)d\theta, \; h \epsilon (0,1)$$

$[1 - R(h,x)]$ is the measure of the stochastic size of a given health prospect.

Notice that definitions 1 and 2 imply that as F becomes larger, its size becomes smaller, and vice versa.

Definition 3. A factor (parameter) x_i is said to be beneficial (harmful) to the consumer's health prospect if

$$R_i = \int_0^h F_i d\theta < 0 \; (> 0)$$

If a factor x_i is beneficial to the consumer's health prospect, it is also plausible to assume that it exhibits diminishing returns. Likewise, if x_i is harmful to the consumer's health prospect, we assume that the harm will increase at an increasing rate. In both cases,[6]

$$R_{ii} > 0$$

Definition 4. The factors x_i and x_j are said to be biased toward benefit if $R_{ij} \leq 0$ and toward harmfulness if $R_{ij} \geq 0$.

Notice from our definitions that two factors may be biased toward benefit (harmfulness) regardless of the benefit or harm each one may produce on its own. For example, two factors could be benefit-biased even though each is classified as harmful, although it is difficult to think of good examples.

As previously indicated, we suppose that there are three factors that can directly affect the distribution function F, two of which are the consumer's present outlays for consumption and prevention, and the third being the general health environment that is beyond the consumer's influence. The inclusion of the choice variables Z and C_1 as parameters in F is not standard and warrants further elaboration. Since these effects turn out to be very similar, we restrict our discussion here to the effect of Z on F.

Suppose that the individual has access to a set of future health prospects wherein each prospect $F \in \mathcal{F}$ is a probability distribution associated with an expenditure level Z. The mapping from Z to $\mathcal{F}$ is, however, not one-to-one. A person does not literally purchase a health prospect. Rather, he buys a particular bundle or mix of medical goods and services with a given sum of money. Since each expenditure level may purchase several, perhaps many, mixes of medical goods and services, there corresponds to each Z a whole set of health prospects $\mathcal{F}_Z$. Stochastic dominance permits us to confine our attention to the efficient set of prospects on the boundary of $\mathcal{F}_Z$. The concept asserts that for all risk-averse individuals a prospect G is preferred to a prospect F if and only if G is larger than F, as specified in Definition 1. Hence, we can assume that for a given Z our consumer will always choose a mix of medical goods and services that yields a dominant prospect as ordered by the relation $\mathcal{D}$.

Let $F^e(h,Z')$ be the dominant (i.e., the largest) probability distribution corresponding to the expenditure level Z'. As shown in Figure 1, $F^e(h,Z')\mathcal{D}F(h,Z')$ if in the closed interval $(0,h)$ the area under the distribution function $F^e(h,Z')$ is no greater than the area under any other distribution function $F(h,Z')$. The connection between R and Z is shown in Figure 2. For the expenditure level $Z', R(h,Z')$ is inversely related to the size of the distribution $F(h,Z')$. The region has an upper bound equal to 1, which reflects the worst possible health state regardless of the amount of money spent to

FIGURE 1

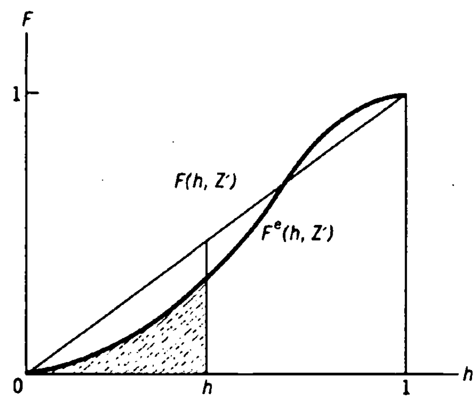
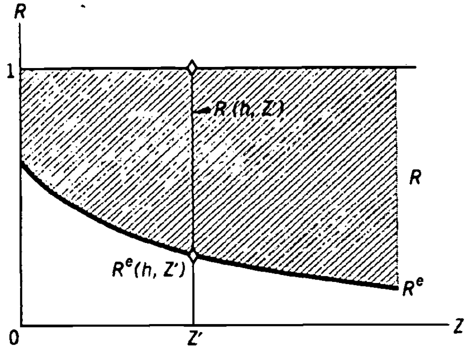


FIGURE 2



prevent it. The lower bound $R^e \epsilon \mathfrak{R}$ is the locus of points representing the size of the dominant distribution for each and every conceivable outlay on preventive medicine. It is reasonable to assume that the efficiency frontier R^e decreases monotonically and is convex, reflecting both the general benefits to future health derived from larger outlays on preventive medicine and the diminishing marginal effectiveness of such activity.

Risk Aversion

When an individual's utility function is represented by a von Neumann-Morgenstern utility index $\phi(W)$ with $\phi'(W) > 0$, where W denotes his wealth, the individual is said to be globally risk averse if $\phi''(W) < 0$ for all W. To measure the *degree* of risk averseness, Arrow (1971, Ch. 3) and Pratt (1964) have defined a coefficient of absolute risk aversion

$$R_A(W) = -\frac{\phi''(W)}{\phi'(W)}$$

where, for small risks, R_A is a function of the maximum sum, or insurance premium, that the individual is willing to pay in order to avoid a given risk. It is generally supposed that an increase in the individual's wealth will reduce the maximum premium that he is willing to pay; i.e.,

$$\frac{dR_A}{dW} < 0$$

This proposition is widely known as the hypothesis of decreasing absolute risk aversion.

In the temporal framework postulated in this paper, the individual's utility function is represented by a von Neumann-Morgenstern utility index $u(C_1,c_2)$, where C_1 and c_2 denote present and future consumption, respectively, with C_1 certain and c_2 uncertain. With respect to future consumption, the individual is said to be risk averse if $u_{22}(C_1,c_2) < 0$. To measure the individual's aversion to risk, Sandmo (1969) has suggested the temporal risk-aversion coefficient

$$A(C_1,c_2) = -\frac{u_{22}(C_1,c_2)}{u_2(C_1,c_2)}$$

where $A(C_1,c_2)$ is also a function of the maximum premium that the individual is willing to pay when faced with a given risk. Analogous to the Arrow-Pratt hypothesis of decreasing absolute risk aversion, Sandmo proposed the following for the two-period case:

Definition 5. The individual's preferences are said to exhibit decreasing temporal risk aversion if

$$\frac{\partial A(C_1,c_2)}{\partial C_1} > 0 \quad \text{and} \quad \frac{\partial A(C_1,c_2)}{\partial c_2} < 0$$

According to the principle of decreasing temporal risk aversion, (1) the higher the individual's present consumption, the greater the risk premium he is willing to pay in order to avoid a given gamble on future consumption, and (2) the higher his future consumption, the lower will be the risk premium. Notice that

$$\frac{\partial A(C_1,c_2)}{\partial C_1} > 0 \text{ implies that } u_{122}(C_1,c_2) < 0$$

and

$$\frac{\partial A(C_1,c_2)}{\partial c_2} < 0 \text{ implies that } u_{222}(C_1,c_2) > 0$$

Moral Hazard

In order to take advantage of the law of large numbers, suppliers of insurance must maintain safeguards so that the underlying stochastic law is not undermined as a consequence of providing the service. More specifically, the insurer must be certain that the act and the manner of insuring persons against a hazardous event or misfortune does not increase the frequency of its occurrence or amount of the claim. Often, the insured has the power to increase the probability of a hazardous event—either through deceptive or fraudulent behavior or through legitimate means.[7]

Definition 6. Moral hazard refers to the phenomenon whereby the method of insurance and the form of the insurance policy affect the behavior of the insured and, therefore, the probabilities on which the insurance company has relied (Arrow, 1971, Chs. 8 and 9; Pauly, 1968).

The presence of moral hazard is a real cost in the production of insurance protection and, hence, a genuine limit to its supply. Completely apart from the opportunities for fraudulent behavior, moral hazard arises in our problem because the consumer of health insurance can affect his future health prospect by changing his present pattern of consumption. If a change in the terms of the policy $(pI, x(h)I)$ causes the individual to purchase more insurance and less prevention, we have a clear instance of "moral" hazard.

Preliminary inspection of the constraints in our model also suggests several possible sources of moral hazard. It seems reasonable to suppose that pre-insurance income is a monotone increasing concave function of the health state reflecting diminishing returns; i.e., $y_2'(h) > 0$ and $y_2''(h) < 0$. Of course, post-insurance income can take many forms, depending on the payoffs $x(h)I$. Obviously, the insurance company would try to avoid the sale of contracts that (1) would make post-insurance income in better health states smaller than in worse health states, and (2) would make any payments in the state of perfect health. In order to avoid these pitfalls, the insurance company must offer a payoff schedule satisfying

Condition 1. $y_2(h) + x'(h)I > 0 \qquad \text{for all } h \in (0,1)$

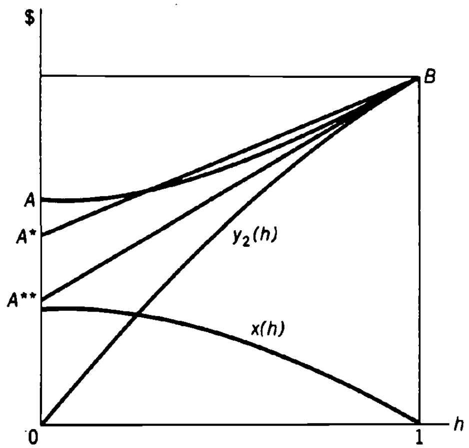
and

Condition 2. $$x(h)I \begin{cases} = 0 & \text{for } h = 1 \\ < y_2(1) - y_2(h) & \text{for } h = 0 \end{cases}$$

These conditions imply a monotonic decreasing payoff schedule.

Furthermore, in order to increase the size of a policy without inducing moral hazard, the insurance company will never choose a concave payoff schedule. Abstracting from the use of deductibles, we show that, given any concave schedule, there always exists a non-concave schedule that will yield a greater revenue for the insurance company. Let $x(h)$ in Figure 3 be a concave payoff

FIGURE 3



schedule and let $(I^0, x(h)I^0)$ be the largest insurance policy an individual can buy without violating conditions 1 and 2. In order to facilitate our analysis, let us construct a new curve, BA, where $BA = y_2(1) - x(h)I^0$. If $[I^0, x(h)I^0]$ is the maximum insurance policy given $x(h)$, then BA is tangent to OB at the point B. Now let $[I^*, x^*(h)I^*]$ be a policy with a linear payoff schedule $x^*(h)$, which is actuarially equivalent to $[I^0, x(h)I^0]$, and let $BA^* = y_2(I) - x^*(h)I^*$. Then it is evident that $[I^*, x^*(h)I^*]$ is not the largest policy that can be sold under the restriction of conditions 1 and 2. The largest linear policy is $[I^{**}, x^*(h)I^{**}]$, where $I^{**} > I^*$, with $BA^{**} = y_2(1) - x^*(h)I^{**}$. Following the same reasoning, a payoff schedule convex to the origin may improve the insurance company's revenue still further. In order to avoid violating conditions 1 and 2, however, the payoff schedule cannot be excessively convex. In fact, the limiting BA curve for convex schedules is OB itself. This result leads to a further restriction on the payoff schedule.

Condition 3. $x''(h) \geq 0$ and $y_2''(h) + x''(h)I < 0$

From these conditions we see that insurance companies must steer a fine course between "the rock" of moral hazard and the "whirlpool" of unattractive and unsalable policies. Ideally, coverage should be carefully tailored to the requirement of every client, but the heterogeneity of the population and the cost of information place definite limitations on this approach. Various devices such as coinsurance and deductibles are used, and though some work better than others, it is readily apparent that none is perfect.

3. THE BASIC MODEL

In this section we present the model in which it is assumed that the consumer maximizes a von Neumann-Morgenstern expected utility with the probability distribution of the health index dependent only on preventive medicine and the general health environment. From equations (1)–(3) we see that the consumer's problem is to choose I and Z so as to maximize[8]

$$U(I,Z) = \int_0^1 u[Y_1 - \rho I - Z, y_2(h,\alpha) + x(h,\beta)I]dF(h;Z,\gamma) \tag{4}$$

where Y_1, α, ρ, β, and γ are parameters. The following assumptions are imposed both to generate stability of equilibrium and to produce some meaningful predictions concerning various equilibrium displacements.

Assumption 1. The consumer's utility function is strictly concave, and present and future consumption are noncompetitive; i.e.,

$$u_{11}, u_{22} < 0 \text{ and } u_{12} \geqslant 0$$

Assumption 2. The consumer exhibits decreasing temporal risk aversion; i.e.,

$$\frac{\partial A}{\partial C_1} > 0 \text{ and } \quad \frac{\partial A}{\partial c_2} < 0$$

Assumption 3. Both pre-insurance and post-insurance future income are increasing concave functions of the future health state; i.e.,

$y_2'(h) > 0$ and $y_2''(h) < 0$, and $y_2'(h) + x'(h)I > 0$ and $y_2''(h) + x''(h)I < 0$, for $h \in (0,1)$

Assumption 4. The insurance payoff schedule is a decreasing convex function of the future health state; i.e.,

$x'(h) < 0$ and $x''(h) \geqslant 0$, for $h \in (0,1)$

From Assumption 3, we also have

$$x''(h) < -\frac{1}{I}y_2''(h)$$

Assumption 5. Expenditure for preventive medicine is beneficial to future health, subject to diminishing returns; i.e., $R_Z < 0$ and $R_{ZZ} > 0$. An increase in the riskiness of the general health environment reduces the size of the prospect; i.e., $R_\gamma > 0$, where γ is a risk-shift parameter.

Assumption 6. Preventive medicine and risk are biased toward benefit; i.e.,

$R_{Z\gamma} \leq 0.$

Equilibrium Conditions

Suppose that an interior solution to the problem exists. Then the first-order equilibrium conditions are

(5.1) $$\int_0^1 u_1 dF = \frac{1}{\rho}\int_0^1 x u_2 dF$$

and

(5.2) $$\int_0^1 u_1 dF = \int_0^1 u dF_Z$$

Equations (5.1) and (5.2), respectively, supply the requirements for the optimal outlay on insurance and preventive medicine. The optimal outlay on insurance equates the expected marginal utility of present consumption with the expected marginal utility of future consumption, the latter weighted by the insurance payoff schedule and discounted by ρ. The optimal outlay on preventive medicine equates the expected marginal utility of present consumption with the gain in expected utility caused by an increment in spending on preventive medicine. Notice that the consumer must believe that money spent for preventive medicine will have a positive influence on his health prospect, no matter how small, otherwise he will spend nothing on it.

The implication of these first-order conditions can best be appreciated by comparing them with their counterparts in a single-period decision model. In the context of a single period, the optimal insurance equalizes income in all states as long as the insurance is actuarially fair. Moreover, in the special case in which prevention does not raise expected income, and barring moral hazard, a corollary proposition is that demand for prevention will be zero because full insurance eliminates the pecuniary advantage otherwise present in shifting the probabilities of particular events. These results do not obtain in the multiperiod model, however, for the simple reason that both insurance and prevention have positive opportunity costs in terms of present consumption. Thus, in general, the optimal outlay for prevention will be positive and the optimal insurance will be less than full coverage.

The equilibrium derived from Equation (5) is stable if

$$D = \begin{bmatrix} U_{II} & U_{IZ} \\ U_{ZI} & U_{ZZ} \end{bmatrix}$$

is negative definite, where

$$U_{II} = \int_0^1 (\rho^2 u_{11} - 2\rho x u_{12} + x^2 u_{22}) dF$$

$$U_{ZI} = U_{IZ} = \int_0^1 (\rho u_{11} - x u_{12}) dF = \int_0^1 (\rho u_1 - x u_2) dF_Z$$

$$U_{ZZ} = \int_0^1 u_{11} dF - 2\int_0^1 u_1 dF_Z + \int_0^1 u dF_{ZZ}$$

Negative definiteness of D requires that U_{II}, $U_{ZZ} < 0$ and $U_{II}U_{ZZ} > U_{IZ}^2$. $U_{II} < 0$ is guaranteed by Assumption 1. $U_{ZZ} < 0$ is guaranteed by assumptions 1–6 (see propositions 2 and 3 in the Appendix). In general, there is no *a priori* reason for signing U_{IZ}; however, in this case, the conditions that guarantee U_{II} and U_{ZZ} negative also make U_{IZ} negative.

Equilibrium Displacements

From (5), I and Z can be expressed as functions of the parameters Y_1, α, ρ, β, and γ. A shift in any one of them will change the optimal values of I and Z. In this subsection we examine and interpret these comparative static results. Notice that assumptions 1–6 not only guarantee that D is negative definite and U_{IZ} is negative,[9] but they also aid us in determining the signs of terms in the comparative statics.

1. A Change in Present Income

The optimal changes in I and Z following a change in Y_1 are

$$(6.1) \qquad \frac{\partial I}{\partial Y_1} = \frac{\left[\int_0^1 (\rho u_{11} - x u_{12}) dF\right] U_{ZZ}}{|D|} + \frac{\left(-\int_0^1 u_{11} dF + \int_0^1 u_1 dF_Z\right) U_{IZ}}{|D|}$$

$$(6.2) \qquad \frac{\partial Z}{\partial Y_1} = \frac{\left(\int_0^1 u_{11} dF - \int_0^1 u_1 dF_Z\right) U_{II}}{|D|} + \frac{\left[-\int_0^1 (\rho u_{11} - x u_{12}) dF\right] U_{ZI}}{|D|}$$

It is convenient to interpret the first term on the right-hand side of (6.1) and (6.2) as the *direct* income effect; it would measure the impact of a change in present income on the amount of insurance and preventive medicine purchased in the event that insurance and preventive medicine were independent alternatives; i.e., if $U_{IZ} = U_{ZI} = 0$. The second term on the right-hand side of (6.1) and (6.2) can then be called the *indirect* income effect; it measures the influence of any interdependence. Given assumptions 1–6, Proposition 2, and the stability requirement, the direct income effect on both I and Z is positive and the indirect income effect is negative. Of course, the total effect in each case is ambiguous, which is not unusual for pure income effects. The important implication is that since insurance and preventive medicine are competitive options, either one (perhaps both) could turn out to be *inferior* with respect to a change in present income.

2. A Change in Future Income

It is convenient to assume that the shift parameter for future income is nonstochastic and takes the form $\frac{\partial y_2(h, \alpha)}{\partial \alpha} = a$, where $a > 0$. Then the partial derivatives of I and Z with respect to α are:

$$(7.1)\qquad \frac{\partial I}{\partial \alpha} = a \left\{ \frac{\left[\int_0^1 (\rho u_{12} - x u_{22}) dF\right] U_{ZZ}}{|D|} + \frac{\left(-\int_0^1 u_{12} dF + \int_0^1 u_2 dF_Z\right) U_{IZ}}{|D|} \right\}$$

$$(7.2)\qquad \frac{\partial Z}{\partial \alpha} = a \left\{ \frac{\left(\int_0^1 u_{12} dF - \int_0^1 u_2 dF_Z\right) U_{II}}{|D|} + \frac{\left[-\int_0^1 (\rho u_{12} - x u_{22}) dF\right] U_{ZI}}{|D|} \right\}$$

As in the first case, the effect of a change in future income is separable into two parts with definite but opposite signs. However, the signs are now reversed. The first term on the right-hand side of (7.1) and (7.2) is negative and the second is positive. The direct income effect is now negative because, ignoring any cross effects, an increase in future income makes the purchase of insurance and preventive medicine less urgent. But the competitive nature of the two services produces an offsetting positive response so that we cannot definitely sign the total effect. In this case, if the direct effect on insurance (preventive medicine) outweighs the indirect effect, then insurance (preventive medicine) is inferior with respect to a change in future income. Notice also, since insurance and prevention are substitutes, the demand for either one (perhaps both) could increase with a rise in future income.

3. A Change in the Price of Insurance

From the individual's point of view, a variation in the price of insurance can take two forms: (1) a change in the private per unit cost ρ, and (2) a change in the payoff schedule $x(h)$. These price effects, however, are not symmetrical.

The displacement in the optimal values of I and Z with respect to a change in ρ can be divided into two parts, a present income effect and an intertemporal substitution effect:

$$\frac{\partial I}{\partial \rho} = -I \frac{\partial I}{\partial Y_1} + \frac{\left(\int_0^1 u_1 dF\right) U_{ZZ}}{|D|} \tag{8.1}$$

$$\frac{\partial Z}{\partial \rho} = -I \frac{\partial Z}{\partial Y_1} + \frac{-\left(\int_0^1 u_1 dF\right) U_{ZI}}{|D|} \tag{8.2}$$

As we have seen in 3.1 (p. 47), the signing of the income effect depends on the relative magnitude of the direct and indirect terms. The sign of the substitution effect, however, is definite: It is negative in (8.1) and positive in (8.2). If insurance and prevention are both "normal goods" with respect to present income—which we feel is a very plausible assumption—then $\partial I/\partial \rho < 0$; i.e., a fall in the private cost of insurance will lead to an increase in demand for it. However, the sign of $\partial Z/\partial \rho$ is ambiguous. If it is positive, then a fall in the private cost of insurance will promote moral hazard.

Now assume that there is a change in the insurance payoff schedule $x(h)$. For simplicity, we suppose that the change is proportional to the original schedule; i.e.,

$$\frac{\partial x(h, \beta)}{\partial \beta} = bx(h, \beta^0)$$

where $b > 0$. Then the displacements of I and Z with respect to a change in β are:

$$\frac{\partial I}{\partial \beta} = bI \left\{ \frac{\left[\int_0^1 x(\rho u_{12} - xu_{22}) dF\right] U_{ZZ}}{|D|} + \frac{\left(-\int_0^1 xu_{12} dF + \int_0^1 xu_2 dF_Z\right) U_{IZ}}{|D|} \right\} - \frac{b\left(\int_0^1 xu_2 dF\right) U_{ZZ}}{|D|} \tag{9.1}$$

$$(9.2)\quad \frac{\partial Z}{\partial \beta} = bI \left\{ \frac{\left(\int_0^1 xu_{12}dF - \int_0^1 xu_2 dF_Z\right) U_{II}}{|D|} + \frac{\left[\int_0^1 x(-\rho u_{12} + xu_{22})dF\right] U_{ZI}}{|D|} \right\} + \frac{b\left(\int_0^1 xu_2 dF\right) U_{ZI}}{|D|}$$

We see immediately that the first two terms are future income effects. However, the expressions in the brackets are different from those in 3.2 in that the utility terms are weighted by the insurance payoffs. This difference does not change the signs of the direct and indirect income effects, but it may change the sign of the combined effect. The remaining term in (9.1) and (9.2) is again the intertemporal substitution effect; it is positive for insurance and negative for prevention. What can be said of the total effects? Assuming that the direct income effect dominates in (8.1) and (8.2), then insurance and prevention are both "inferior goods." Since in the case of insurance the substitution effect is positive, a proportional change in future insurance payoffs produces an ambiguous effect on the demand for insurance; $\partial I/\partial \beta > 0$ only if the substitution effect outweighs the combined income effect. Since in the case of prevention the income and substitution effects are both negative, the proportional change in payoff produces a definite negative effect on the demand for preventive medicine.

We emphasize in passing that although a change in ρ and a proportional change in $x(h)$ both produce income and substitution effects, in general they are not the same. The difference stems from the fact that a change in ρ produces a combined present income effect and a substitution effect involving present marginal utility, whereas the change in $x(h)$ produces a combined future income effect and a substitution effect involving future marginal utility.

4. A Change in Risk

Suppose that there is an exogenous change in the riskiness of the general health environment. Let a change in the parameter γ generate a mean-preserving change in the spread of all health prospects $F \in \mathcal{F}$; i.e., $R_\gamma(h, \cdot) \geqslant 0$, with the equality holding for $h = 1$. Then the effects of a change in γ on the optimal levels of I and Z are:

$$(10.1)\quad \frac{\partial I}{\partial \gamma} = \frac{\left[\int_0^1 (\rho u_1 - xu_2)dF_\gamma\right] U_{ZZ}}{|D|} + \frac{\left(-\int_0^1 u_1 dF_\gamma + \int_0^1 udF_{Z\gamma}\right) U_{IZ}}{|D|}$$

$$(10.2)\quad \frac{\partial Z}{\partial \gamma} = \frac{\left(\int_0^1 u_1 dF_\gamma - \int_0^1 udF_{Z\gamma}\right) U_{II}}{|D|} + \frac{\left[-\int_0^1 (\rho u_1 - xu_2)dF_\gamma\right] U_{ZI}}{|D|}$$

Notice that as in the case of income effects, it is possible to divide the change in the optimal values of I and Z into two parts. We call the first and the second terms of (10.1) and (10.2), respectively, the direct and indirect risk effects. In order to sign these separate terms, we only need to sign the coefficients

$$\int_0^1 (\rho u_1 - xu_2)dF_\gamma$$

and

$$\left(\int_0^1 u_1 dF_\gamma - \int_0^1 udF_{Z\gamma}\right)$$

By propositions 1 and 3 in the appendix, both coefficients are negative. Thus, the direct effects for both insurance and preventive medicine are positive and the indirect effects are negative. The combined effects will, of course, depend on the relative magnitudes of the separate terms.

Previous studies by Leland (1966) and Sandmo (1970) have shown that decreasing temporal risk aversion is sufficient to guarantee that an increase in risk will cause an increase in the optimal amount of saving (in our case, insurance). But we see from our model that the condition is more complex. First, by recognizing prevention as an alternative hedge against uncertainty, our model shows the existence of an indirect risk effect. Second, we find that the sufficient condition for a positive risk effect involves restrictions on the class of payoff functions as well as on the class of utility functions. An important implication of this latter finding is that the insurance company has in its choice of payoff schedule a significant weapon to combat moral hazard.

4. MODEL WITH CONSUMPTION AFFECTING HEALTH PROSPECT

As we mentioned in the introduction, preventive medicine is not the only factor that can influence the consumer's health prospect.

We need not go so far as to say "you are what you consume," but it is hardly controversial to admit that many nonmedical goods and services—food, housing, drink, tobacco—can and often do have an important bearing on future health, either positive or negative. In this section we examine the consumer's optimal outlay on insurance and prevention when present consumption, C_1, is a parameter of F as well as a variable in u. In order to analyze what we believe to be the most interesting case, we make two additional assumptions:

Assumption 7. Changes in present consumption involve goods that are harmful to health, subject to increasing negative returns; i.e.,

$$R_{C_1} > 0, R_{C_1C_1} > 0$$

Assumption 8. Preventive medicine and present consumption are biased toward benefit, and risk and present consumption are biased toward harm; i.e.,

$$R_{ZC_1} \leq 0 \text{ and } R_{\gamma C_1} \geq 0$$

The consumer's expected utility can now be written as

$$V = \int_0^1 u(C_1, c_2) dF(h; Z, C_1, \gamma)$$

where u is again a von Neumann-Morgenstern utility index with continuous derivatives of the first, second, and third order. As in the preceding section the consumer will choose I and Z so as to maximize V subject to the constraints,

$$C_1 = Y_1 - \rho I - Z$$

$$c_2(h) = y_2(h) + x(h)I$$

The first-order maximization conditions become

$$\int_0^1 u_1 dF = \frac{1}{\rho}\int_0^1 x u_2 dF - \int_0^1 u dF_{C_1} \quad (12.1)$$

$$\int_0^1 u_1 dF = \int_0^1 u\,(dF_z - dF_{C_1}) \quad (12.2)$$

and the second-order condition is that the matrix

$$A = \begin{bmatrix} V_{II} & V_{IZ} \\ V_{ZI} & V_{ZZ} \end{bmatrix}$$

is negative definite, where

$$V_{II} = \int_0^1 (\rho^2 u_{11} - 2\rho x u_{12} + x^2 u_{22}) dF + 2\rho \int_0^1 (\rho u_1 - x u_2) dF_{C_1} + \rho^2 \int_0^1 u dF_{C_1 C_1}$$

(13) $$V_{ZZ} = \int_0^1 u_{11} dF + 2\int_0^1 u_1 (dF_{C_1} - dF_Z) + \int_0^1 u (dF_{C_1 C_1} - 2dF_{ZC_1} + dF_{ZZ})$$

$$V_{IZ} = V_{ZI} = \int_0^1 (\rho u_{11} - x u_{21}) dF + \int_0^1 (\rho u_1 - x u_2)(dF_{C_1} - dF_Z)$$

$$+ \rho \int_0^1 u_1 dF_{C_1} + \rho \int_0^1 u (dF_{C_1 C_1} - dF_{ZC_1})$$

The first-order maximization conditions state that when current consumption affects the future health prospect, then (1) the consumer will choose an optimal insurance outlay by equating the expected marginal utility of present consumption with the expected marginal utility of future consumption discounted by ρ, net of the change in the expected utility from a shift in the probability distribution caused by a change in C_1; and (2) he will choose an optimal expenditure on preventive medicine by equating the expected marginal utility of present consumption with the net change in the utility of the health prospect stemming from changes in both Z and C_1. The implications of these first-order conditions can best be seen by comparing the equilibrium values of I and Z with those derived in the preceding section. Given Assumption 7 and according to Proposition 4 in the appendix, we find

$$\int_0^1 u dF_{C_1} < 0$$

Our interpretation is that the optimal present consumption will decrease if it has a harmful effect on the health prospect.[10] Consequently, the optimal outlays I and Z as determined by Equation (12) should be larger than those determined by Equation (5) in Section 3, where C_1 is assumed to have no effect whatsoever on the health prospect.

The second-order maximization conditions specify that V_{II}, $V_{ZZ} < 0$ and $V_{II} V_{ZZ} > V_{IZ}^2$. We will show that assumptions 1–8 are sufficient to make I and Z competitive. Notice first that by Assumption 1,

$$\int_0^1 (\rho u_{11} - x u_{21}) dF < 0$$

Next, by propositions 2–5 in the appendix, we find that the terms

$$\int_0^1 x u_2 dF_{C_1} \text{ and} \int_0^1 u_1 dF_Z$$

are positive, and the terms

$$\int_0^1 u_1 dF_{c_1}, \int_0^1 x u_2 dF_Z \text{ and } \int_0^1 u(dF_{c_1c_1} - dF_{Zc_1})$$

are negative. Then it follows from (13) that

$$V_{IZ} = V_{ZI} < 0$$

Having examined the maximization conditions, let us now turn to the comparative statics. As before, the equilibrium values of I and Z are determined by the parameters Y_1, α, ρ, β, and γ. The consumer's optimal expenditure on insurance and preventive medicine will change whenever there is an exogenous change in any of these parameters. Let the equilibrium values of I and Z be denoted by I^* and Z^*, and let $F^0 = F(h; C_1^0, \cdot)$. Symbolically, the comparative static results are:

(14)
$$\frac{\partial I^*}{\partial Y_1} = \left.\frac{\partial I^*}{\partial Y_1}\right|_{F=F^0} + \left\{ \frac{\left[\int_0^1 (2\rho u_1 - x u_2) dF_{c_1} + \rho \int_0^1 u dF_{c_1c_1}\right] V_{ZZ}}{|A|} + \frac{-\left[2\int_0^1 u_1 dF_{c_1} + \int_0^1 u (dF_{c_1c_1} - dF_{c_1Z})\right] V_{IZ}}{|A|} \right\}$$

$$\frac{\partial Z^*}{\partial Y_1} = \left.\frac{\partial Z^*}{\partial Y_1}\right|_{F=F^0} + \left\{ \frac{\left[2\int_0^1 u_1 dF_{c_1} + \int_0^1 u (dF_{c_1c_1} - dF_{c_1Z})\right] V_{II}}{|A|} + \frac{-\left[\int_0^1 (2\rho u_1 - x u_2) dF_{c_1} + \rho \int_0^1 u dF_{c_1c_1}\right] V_{ZI}}{|A|} \right\}$$

(15)
$$\frac{\partial I^*}{\partial \alpha} = \left.\frac{\partial I^*}{\partial \alpha}\right|_{F=F^0} + a \frac{\int_0^1 u_2 dF_{c_1} (\rho V_{ZZ} - V_{IZ})}{|A|}$$

$$\frac{\partial Z^*}{\partial \alpha} = a \left.\frac{\partial Z^*}{\partial \alpha}\right|_{F=F^0} + a \frac{\int_0^1 u_2 dF_{c_1} (V_{II} - \rho V_{ZI})}{|A|}$$

(16)
$$\frac{\partial I^*}{\partial \rho} = \left.\frac{\partial I^*}{\partial \rho}\right|_{F=F^0} - I \left\{ \frac{\partial I^*}{\partial Y_1} - \left.\frac{\partial I^*}{\partial Y_1}\right|_{F=F^0} \right\} + \frac{\left(\int_0^1 u dF_{c_1}\right) V_{ZZ}}{|A|}$$

$$\frac{\partial Z^*}{\partial \rho} = \frac{\partial Z^*}{\partial \rho}\bigg|_{F=F^0} - I\left\{\frac{\partial Z^*}{\partial Y_1} - \frac{\partial Z^*}{\partial Y_1}\bigg|_{F=F^0}\right\} + \frac{-\left(\int_0^1 udF_{C_1}\right)V_{IZ}}{|A|}$$

(17) $$\frac{\partial I^*}{\partial \beta} = b\,\frac{\partial I^*}{\partial \beta}\bigg|_{F=F^0} + bI\,\frac{\int_0^1 xu_2 dF_{C_1}(\rho V_{ZZ} - V_{IZ})}{|A|}$$

$$\frac{\partial Z^*}{\partial \beta} = b\,\frac{\partial Z^*}{\partial \beta}\bigg|_{F=F^0} + bI\,\frac{\int_0^1 xu_2 dF_{C_1}(V_{II} - \rho V_{ZI})}{|A|}$$

(18) $$\frac{\partial I^*}{\partial \gamma} = \frac{\partial I^*}{\partial \gamma}\bigg|_{F=F^0} + \frac{\int_0^1 udF_{\gamma C_1}(\rho V_{ZZ} - V_{IZ})}{|A|}$$

$$\frac{\partial Z^*}{\partial \gamma} = \frac{\partial Z^*}{\partial \gamma}\bigg|_{F=F^0} + \frac{\int_0^1 udF_{\gamma C_1}(V_{II} - \rho V_{ZI})}{|A|}$$

To simplify our notation, let

$t = (Y_1, \alpha, \rho, \beta, \gamma)$

In equations (14)–(18), the terms

$$\frac{\partial I^*}{\partial t}\bigg|_{F=F^0} \text{ and } \frac{\partial Z^*}{\partial t}\bigg|_{F=F^0}$$

have the same general form as the terms

$$\frac{\partial I}{\partial t} \text{ and } \frac{\partial Z}{\partial t}$$

in equations (6)–(10) of the basic model. The difference is that V_{II}, V_{IZ},V_{ZZ} and $|A|$ are substituted for U_{II}, U_{IZ}, U_{ZZ} and $|D|$. Since U_{ij} and V_{ij}, $i,j = IZ$ are all negative, it is evident that the individual terms in

$$\frac{\partial I^*}{\partial t}\bigg|_{F=F^0} \text{ and } \frac{\partial Z^*}{\partial t}\bigg|_{F=F^0}$$

must have the same signs as the corresponding terms in

$$\frac{\partial I}{\partial t} \text{ and } \frac{\partial Z}{\partial t}$$

But because the magnitudes vary, the corresponding total effects may be different.

The remaining terms in equations (14)–(18) are new. They measure the effects of consumption-induced shifts in the health prospect on the optimal outlays for health insurance and preventive medicine. Observe that each coefficient shown contains a first- or second-order differential of F caused by the displacement of present consumption, C_1. Notice also that most of the additional terms can be properly classified as supplementary income or risk effects. The exception is Equation (16), in which there is also a supplementary substitution effect. It may seem odd at first glance that β does not generate an additional substitution term, but the explanation is to be found in the fact that size of marginal loss caused by consumption-induced harm to the future health prospect is proportional only to ρ, the private unit cost of insurance.

The predictions on the additional terms are exactly parallel to those in the preceding section. The income and risk effects can be divided into separate direct and indirect terms of definite and corresponding signs. Given assumptions 1–8, we find that

$$\int_0^1 u_1 dF_{C_1}, \int_0^1 udF_{C_1C_1} \text{ and } \int_0^1 udF_{\gamma C_1}$$

are negative and

$$\int_0^1 udF_{C_1} \text{ and } \int_0^1 udF_{ZC_1}$$

are positive. Hence the separate supplemental terms are all signed, but the combined effects are ambiguous. Again, the outcome in each case depends on the relative magnitudes of the opposing direct and indirect effects. The supplementary substitution terms in Equation (16) are definitely signed, but they are opposite from those in the basic model. However, the equilibrium conditions require

$$\int_0^1 u_1 dF + \int_0^1 udF_{C_1} > 0$$

where

$$\int_0^1 u_1 dF$$

is a term in

$$\left.\frac{\partial I^*}{\partial \rho}\right|_{F=F^0}$$

so that the signs of the combined substitution effects in the extended model are the same as in the basic model.

To summarize, the presence of consumption as a harmful influence on future health will increase the optimal outlay on insurance and prevention over what it would be otherwise. But given assumptions 7–8, the qualitative nature of the comparative static results derived in the basic model remains unchanged, although the magnitudes are likely to be different.

5. SUMMARY AND CONCLUSIONS

The problem studied in this paper is the optimal choice of health insurance and preventive medicine for an individual faced with uncertain future health. Insurance and prevention are fundamentally different approaches to health planning in that the former transfers income from the present to hazardous states in the future whereas the latter alters present consumption to benefit future health prospects. Our analysis is limited to the case in which the principal effect of the state of health is on net income (current earnings less necessary medical expenses), but we freely acknowledge the potential importance of health as a direct influence on consumer preferences.

In the basic model, we assume that current consumption can be partitioned into three mutually exclusive categories: insurance, pure prevention, and other consumption outlays. In this instance, preventive activity is assumed to have no direct influence on utility, and consumption is assumed free of any effects on future health prospects. In the extended model, we include a category of consumption in which the influence is mixed.

As is well known, the expected utility model is very general in the sense of admitting a wide range of risk attitudes and a broad set of probability distributions. In the context of optimal insurance and prevention, it is plausible to suppose that we are dealing with a generally risk-averse population and a set of prospects ordered by stochastic dominance. A few additional and, we hope, quite reasonable assumptions enable us to guarantee stability of equilibrium and to derive several meaningful results.

An important finding is that insurance and prevention are strictly competitive (net substitutes). This result has immediate implications for equilibrium displacements caused by changes in wealth, the amount of uncertainty in the environment, and the price of insurance. Total income effects turn out to be ambiguous, but we can definitely sign separate direct and indirect effects. If, as is likely, the direct effects outweigh the indirect effects, the combined effects are also signed: The demand for insurance and prevention will vary directly with present income and inversely with future income. Likewise, there are separate direct and indirect risk effects; again, if the direct effect is dominant, we predict that the demand for insurance and prevention will vary directly with the greater riskiness of the health environment. In addition to income effects, changes in the price of insurance yield definite substitution effects: A fall in the price of insurance (in the form of either a decline in the premium or a rise in benefits) will increase the amount of insurance and decrease the outlay on prevention. If the sign relationship between the combined income effect and the substitution effect produces a fall in the price of insurance and causes the individual to increase the optimal outlay on insurance and to decrease the optimal outlay on prevention, then we have a clear case of moral hazard.

There are further implications in this study concerning the phenomenon of moral hazard. The insurance company has within its control a device—the selection of a payoff schedule (together with deductibles and coinsurance)—to prevent moral hazard. The desired schedule must avoid any coverage that will cause post-insurance income to rise with greater misfortune or to increase at an increasing rate with an improved health state. A schedule with these characteristics can produce a bias toward insurance and against prevention and, hence, promote moral hazard.

The competitive character of insurance and prevention poses a problem in designing an efficient national health insurance program. Our analysis suggests that efforts to extend the coverage of health insurance through public subsidy should be weighed against the cost arising from possible reductions in the demand for prevention. Although we know of no way to avoid this opportunity cost altogether, it can and undoubtedly should be minimized. We see here that the terms of insurance potentially provide an important instrument of control. For example, if the price of insurance is reduced by a public subsidy to stimulate demand, there may be important differences in the way people respond, depending on whether the subsidy (1) reduces the current expenditure or (2) increases the future payoffs. In case (1), we would predict an increase in the volume of insurance because both the income and the substitution effects are likely to be negative. Moral hazard is indicated if the negative income effect on preventive expenditure is not outweighed by the positive cross-substitution effect. In other words, our model demonstrates that the income effect generated by a decline in the proportion of the premium paid by the beneficiary acts as a check on the tendency to substitute insurance protection for prevention. Of course, the importance of this restraint on moral hazard depends on the relative size of the income and substitution effects. As medical expenses and related costs of health care typically claim a significant share of budgets of middle- and low-income receivers, income effects are also likely to be significant.[11] In case (2), when the price reduction takes the form of a subsidy to future payoffs, the situation is reversed. The problem of moral hazard is now inescapable since both the income and substitution effects are negative. Any such implications, of course, must be qualified by possible limitations in the nature and the scope of the model. In particular, we recognize that the assumption of a state-independent utility function does bias our result toward insurance and against prevention, which tends to exaggerate the problem of moral hazard.

APPENDIX

Proposition 1. Let the shift in γ be a mean preserving increase in the spread of F. Given assumptions 1–4, then

$$\int_0^1 (u_1 - xu_2)dF_\gamma < 0$$

Furthermore,

$$\int_0^1 u_1 dF_\gamma < 0 \text{ and } \int_0^1 xu_2 dF_\gamma > 0$$

Proof. Integrating by parts twice, we obtain

$$\int_0^1 (u_1 - xu_2)dF_\gamma = -[(u_{12} - xu_{22})(y_2 + x'I) - x'u_2]R_\gamma(h,z,\gamma)\Big|_0^1$$

$$+ \int_0^1 [(u_{122} - xu_{222})(y_2' + x'I)^2 + (u_{12} - xu_{22})(y_2'' + x''I)$$

$$- 2u_{22}x'(y_2' + x'I) - u_2 x'']R_\gamma(h,z,\gamma)dh$$

(i) $\quad -(\cdot)R_\gamma(h,z,\gamma)\Big|_0^1 = 0$

follows from the assumption that the shift in γ represents a mean preserving increase in spread.

(ii) $(u_{122} - xu_{222})(y_2' + x'I)^2 < 0$

follows from A.2.

(iii) $(u_{12} - xu_{22})(y_2'' + x''I) < 0$

follows from A.1 and A.3.

(iv) $2u_{22}x'(y_2' + x'I) > 0$ and $u_2x'' \geqslant 0$

follow from A.3 and A.4. Therefore,

$$\int_0^1 (u_1 - xu_2)dF_\gamma < 0$$

Following the same reasoning,

$$\int_0^1 u_1 dF = \int_0^1 [u_{122}(y_2' + x'I)^2 + u_{12}(y_2'' + x''I)]R_\gamma(h,z,\gamma)dh < 0$$

and

$$\int_0^1 u_2 x dF_\gamma = \int_0^1 [u_{222}x(y_2' + x'I)^2 + 2u_{22}x'(y_2' + x'I)$$

$$+ u_{22}x(y_2'' + x''I) + u_2 x''] R_\gamma dh > 0$$

***Proposition* 2.** Let the factor Z be beneficial to the consumer's health prospect. Given assumptions 1–4, then

$$\int_0^1 (u_1 - xu_2)dF_Z > 0$$

Furthermore,

$$\int_0^1 u_1 dF_Z > 0,\ \int_0^1 xu_2 dF_Z < 0, \text{ and } \int_0^1 u_2 dF_z < 0$$

Proof. Integrating by parts twice, we obtain

$$\int_0^1 (u_1 - xu_2)dF_Z = -[(u_{12} - xu_{22})(y_2' + x'I) - x'u_2]R_Z(h,Z,\gamma)\Big|_0^1$$

$$+\int_0^1 [(u_{122} - xu_{222})(y_2' + x'I)^2 + (u_{12} - xu_{22})(y_2'' + x''I)$$

$$- 2u_{22}x'(y_2' + x'I) - u_2x'']R_Z(h,Z,\gamma)dh$$

(i) $-[(u_{12} - xu_{22})(y_2' + x'I) - x'u_2]R_Z(h,Z,\gamma)\Big|_0^1$

$= -[(u_{12} - xu_{22})(y_2' + x'I) - x'u_2]R_Z(1,Z,\gamma)$

follows from the fact that $R_Z(0,Z,\gamma) = 0$.

(ii) $R_z(1,Z,\gamma) < 0$ follows from the assumption that Z is beneficial to the consumer's health prospect. $(u_{12} - xu_{22})(y_2' + x'I) > 0$ follows from A.1 and A.3, and $x'u_2 < 0$ follows from A.4. Therefore, $-(\cdot)R_z(1,Z,\gamma) > 0$.

(iii) $\int_0^1 (u_1 - xu_2)dF_Z > 0$, $\int_0^1 u_1 dF_Z > 0$, and $\int_0^1 xu_2 dF_Z < 0$

can be shown with the same reasons given in Proposition 1.

(iv) Similarly, it can be shown that

$$\int_0^1 u_2 dF_Z < 0$$

***Proposition* 3.** Given assumptions 1–6: (a)

$$\int_0^1 u dF_{ZZ} < 0$$

and (b)

$$\int_0^1 u dF_{\gamma Z} \geq 0$$

Proof.

(a) Integrating by parts twice, we obtain

$$\int_0^1 u dF_{ZZ} = uF_{ZZ}(h,Z,\gamma)\Big|_0^1 - u_2(y_2' + x'I)R_{ZZ}(h,Z,\gamma)\Big|_0^1 + \int_0^1 [u_{22}(y_2' + x'I)^2 + u_2(y_2'' + x''I)]R_{ZZ}(h,Z,\gamma)dh$$

(i) $F_{ZZ}(h,Z,\gamma)dh \equiv 0$ for $h = 0, 1$. Therefore,

$$uF_{ZZ}(h,Z,\gamma)\Big|_0^1 = 0$$

(ii) $$-u_2(y_2' + x'I)R_{ZZ}(h,Z,\gamma)\Big|_0^1 = -u_2(y_2' + x'I)R_{ZZ}(1,Z,\gamma) < 0$$

follows from A.3 and A.5.

(iii) $$\int_0^1 [u_{22}(y_2' + x'I)^2 + u_2(y_2'' + x''I)]R_{ZZ}(h,Z,\gamma)dh < 0$$

follows from A.1, A.4, and A.5.

(b) Integrating by parts twice, we obtain

$$\int_0^1 u dF_{\gamma Z} = uF_{\gamma Z}(h,Z,\gamma)\Big|_0^1 - u_2(y_2' + x'I)R_{\gamma Z}(h,Z,\gamma)\Big|_0^1 + \int_0^1 [u_{22}(y_2' + x'I)^2 + u_2(y_2'' + x''I)]R_{\gamma Z}(h,Z,\gamma)dh$$

Again, we see that

$$F_{\gamma Z}(h,Z,\gamma)\Big|_0^1 = 0$$

regardless of the changes in γ and Z. By assumption 6, $R_{\gamma Z} \leq 0$. The hypothesis of the proposition thus guarantees

$$\int_0^1 u dF_{\gamma Z} \geq 0$$

which is what we wish to prove.

Proposition 4. Given assumptions 1–4 and 7, (a)

$$\int_0^1 u_1 dF_{C_1} < 0$$

(b)

$$\int_0^1 xu_2 dF_{C_1} > 0$$

and (c)

$$\int_0^1 u dF_{C_1} < 0$$

Proof.

(a) Integrating by parts twice,

$$\int_0^1 u_1 dF_{C_1} = -u_{12}(y_2' + x'I)R_{C_1}(h,Z,C_1,\gamma)\,\Big|_0^1 + \int_0^1 \left[u_{12}(y_2'' + x''I) + u_{122}(y_2' + x'I)^2\right] R_{C_1}(h,Z,C_1,\gamma)dh$$

(i) $R_{C_1}(0,Z,C_1,\gamma) = 0$, and by A.7 $R_{C_1}(1,Z,C_1,\gamma) > 0$. Following A.1 and A.3, therefore,

$$-u_{12}(y_2' + x'I)R_{C_1}(h,Z,C_1,\gamma)\,\Big|_0^1 > 0$$

(ii) A.1–4 and A.7 also imply that

$$\int_0^1 [u_{12}(y_2'' + x''I) + u_{122}(y_2' + x'I)]R_{C_1} dh < 0$$

Therefore,

$$\int_0^1 u_1 dF_{C_1} < 0$$

(b) Following a similar reasoning, we obtain (b) and (c).

Proposition 5. Given assumptions 1, 3, 4, and 8, (a)

$$\int_0^1 u dF_{\gamma C_1} < 0$$

(b)

$$\int_0^1 u dF_{C_1 C_1} < 0$$

and (c)

$$\int_0^1 u dF_{Z C_1} > 0$$

Proof.

(a) Integrating by parts twice, we obtain

$$\int_0^1 u dF_{\gamma C_1} = -u_2(y_2' + x'I)R_{\gamma C_1}(h,Z,C_1,\gamma)\Big|_0^1$$

$$+\int_0^1 [u_{22}(y_2' + x'I)^2 + u_2(y_2'' + x''I)]R_{\gamma C_1} dh$$

(i) Again, $R_{\gamma C_1}(0,Z,C_1,\gamma) = 0$, and by assumption 8, $R_\gamma C_1(1,Z,C_1,\gamma) > 0$. A.3 therefore guarantees the result

$$-u_2(y_2' + x'I)R_{\gamma C_1}(h,Z,C_1,\gamma)\Big|_0^1 < 0$$

(ii) In addition, A.1, A.4, and A.8 guarantee

$$\int_0^1 [u_{22}(y_2' + x'I)^2 + u_2(y_2'' + x''I)]R_{\gamma C_1} dh < 0$$

Therefore,

$$\int_0^1 u dF_{\gamma C_1} < 0$$

(b) The same hypotheses also guarantee

$$\int_0^1 u dF_{C_1 C_1} < 0$$

and

$$\int_0^1 u dF_{Z C_1} > 0$$

except that A.8 refers to $R_{C_1 C_1} > 0$ and $R_{ZC_1} < 0$, respectively.

NOTES

1. Considerable doubt, however, exists in the medical profession regarding the effectiveness of preventive medicine, especially that part concerned with the early detection and treatment of diseases. If preventive medicine is of doubtful value, then why would a rational person purchase any of it? We have no particular ax to grind on this issue except to point out that preventive medicine need not be so narrowly conceived: it might just as well include any consumption activity, medical or otherwise, having a potential benefit on future health. Moreover, the crucial consideration in our model is the individual's *subjective* view of the effectiveness of prevention, the opinions of medical experts to the contrary notwithstanding.
2. Prevention is sometimes characterized as an activity that reduces the probabilities of hazardous states of health. Although this description is correct, it is not the whole story because it is silent on what happens to the probabilities of less hazardous states, including those that are totally free of hazard. As the hypothesis of risk avoidance strongly suggests, prevention is not confined to activities that uniformly "roll up" probabilities toward less hazardous states; it also includes those that reduce the frequencies of both the most and the least

hazardous states but leave the average state of health unaffected. To cite an example: A drug or operation that reduces the chances of a person's becoming very ill may also involve side effects that lower the chances of one's being extremely well. A risk-averse person might favor such a prospect even though it does not offer much hope of raising his health expectation.

3. For analyses based on conditional expected utility, see Arrow (1973), Nordquist (1970), and Parkin and Wu (1972).
4. Future income, y_2, is assumed to be net of (a) anticipated future medical expenses, and (b) reductions in earning power caused by illness. We assume that the individual can purchase insurance to compensate for both sources of loss to future consumption opportunities.
5. In their seminal paper, Ehrlich and Becker (1972) provide a similar analysis in a setting of a single period and two states.
6. We recognize that some factors may be beneficial in some range of consumption and harmful in others.
7. The principal objective of this paper is to develop a rigorous formulation of the joint demand for insurance and prevention. Thus, we adhere to the conventional atomistic specification of consumer choice and decline to make the market price of insurance depend directly on any of the individual's choice variables, as is done in the article by Ehrlich and Becker (1972, p. 640). Although it is quite likely that a *monopolistic supplier* of insurance would perceive and be concerned about the presence of moral hazard, we argue that the same will not be true of the *small and independent purchaser*.
8. Properly specified, the problem should include the further restriction $I \leq I^0$, where I^0 is the premium of the largest insurance policy (with payoff $x(h)I$) that the consumer is allowed to purchase. For simplicity, we assume that this inequality constraint is never binding.
9. We should add the reminder that the conditions cited here are sufficient but not necessary to sign the separate income terms.
10. If a change in present consumption involves goods that are beneficial to health, these results will be reversed.
11. For other possible checks to moral hazard, see Arrow (1971, Ch. 8) and Ehrlich and Becker (1972, pp. 641–642).

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2 COMMENTS

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The influence that variable insurance coverage has on the purchase of preventive services represents a particularly thorny issue in the health care field. In general, we can expect that the consumer will choose such a mix as to maximize his expected utilities. In an open-market situation, in which the individual chooses his expenditures, then there is a real possibility that he might underspend on prevention; that is, he might underspend if preventive services represent a separate good such that the purchase of curative services does not entail the purchase of preventive services. With perfect information he should be expected to choose an optimal mix of insurance and prevention to maximize utility. However, information is imperfect, especially in the health field. Prevention has been oversold as an idea in many areas, except that only some consumers overbuy, such as in purchasing annual physical exams. Prevention makes a big difference if it leads more people to wear seat belts or stop smoking cigarettes, but behavioral modification has been the least successful approach to prevention. Much must be done in educating the public in any system of health care, but the transmission of information alone does not insure compliance with the optimal program.

There is also a considerable problem of moral hazard. It is not so much that the consumer will run great health risks because health care costs are going to be paid with full entitlement or increased entitlement and thus would tend to avoid obtaining necessary preventive services, but that full entitlement will lead to unnecessary hospitalization and unnecessarily long hospitalization with overly expensive work-ups.

Another feature is unnecessary office visits. But who is to define unnecessary office visits? When initiated by a patient, an office visit represents *de facto* demand.

Although all this is true from the point of view of the consumer, the program must face tradeoffs between curative and preventive medicine. Fees will presumably be replaced by capitation payments. In this circumstance, who should determine the contents of the preventive package when the public is so poorly informed? Somebody must accept the responsibility for maximizing societal utilities, and this is difficult to do without knowledge of the value society attaches to the outcomes of medical care. Much additional research is needed on health status indexes and the societal values placed on the conditions of life to provide a basis for such judgments.

Whatever the decision, it may be difficult to keep preventive services within reasonable bounds. With a few crucial exceptions (e.g., the control of hypertension to prevent strokes, and immunizations to prevent certain infectious diseases), prevention is of little use at the present time, regrettably, and we tend to overdo it. On net, the consumer will have little to say about the mix of preventive and curative services, and even when preventive services become more effective, he may well resist diverting money to preventive services if it means longer queues and personal inconvenience.

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This is a very careful and competent investigation of the economics of self-protection. The authors consider a two-period model in which individuals with known health states in the first period reduce second-period medical risk by self-protection and market insurance. Self-protection (i.e., preventive medicine) shifts the actual distribution of risky outcomes. Market insurance doesn't change the distribution, but transfers the risks to others, at a price. As long as preventive expenditures shift the cumulative probability density function of poor health states, they are productive; and individuals extend expenditures in both directions up to the appropriate margins. Of course, the practical importance of self-protection for the allocation of health resources depends on the extent to which it does in fact shift medical risks, a point on which there is little evidence one way or the other.

Nordquist and Wu specialize their argument to a case wherein health states affect only income and not the capacity to consume: They ignore "pain and suffering," which otherwise introduces asymmetry between self-protection and market insurance. Market insurance reduces financial risks but not pain and sufferings, whereas self-protection affects both. Inclusion of health-utility effects involves conceptually straightforward extensions of their methods and perhaps that is sufficient justification for ignoring them at this stage.

Another maintained assumption strikes me as having less justification. Nordquist and Wu assume that the price of market insurance is independent of preventive expenditures. That is, they assume that insurance premiums per dollar of coverage are independent of medical risks individuals choose to run. This could be a valid assumption at the individual level if transactions costs are sufficiently high, for then insurance companies do not find it worthwhile to classify individuals according to risk. But even those factors must be a matter of degree, and the empirical validity of the assumption surely depends on the productivity of preventive expenditures. The observation that insurance companies do not vary premiums across individuals in different risk classes is evidence that policing and information costs are large relative to preventive expenditure productivity on health.

But whatever is the true assumption for any person at random, it surely cannot be true for the market as a whole or for the "representative" individual, as the authors implicitly recognize in discussing moral hazard. Suppose that some exogenous event, such as those considered in the paper, induces all individuals to change self-protection expenditures and thereby to change the average health state among all persons. Insurance companies now experience unanticipated changes in profit, and price competition and new entry must alter premium rates. This sets off another chain, with feedbacks to optimal self-protection expenditures, and so on. All these secondary and higher-order effects are ignored in the paper and how they affect the conclusions is not very obvious. For example, the process depicted above may not be stable. But assuming that it was, some information on the long-run, steady-state response could be obtained if the authors had considered the other polar extreme in which insurance premiums and health state probabilities are perceived to be related to each other rather than completely unrelated.

Some other limitations of the specification should be mentioned.

1. Nordquist and Wu use an index, h, as a health state indicator. What is the operational content of h and precisely what does it measure? Even if health states could be ranked according to an objective univariate index, it still must be an ordinal index. The authors arbitrarily normalize the index to lie between zero and 1, but any monotonic transformation would do just as well. If so, what sense does it make to talk about the convexity of the insurance payoff schedule?
2. As pointed out above, the authors focus only on financial risks of illness. Income (in period two) is what it would have been in the absence of illness minus the cost of medical treatment. Income received from the insurance company in the event of illness, xI, covers some fraction of the medical bill. Thus they assume that illness does not affect earning capacity and, more important, each illness is associated with a unique exogenously determined remedy available to all at a fixed fee. All the much discussed effects of insurance and payments by third parties on the type and quality of care are ignored. Moreover, the quality of care and self-protection may be good substitutes.

Turn now to the theorems established by the authors. For ease of interpretation and exposition, their argument will be simplified by considering a one-period problem and collapsing the continuous distribution of possible health states into a familiar binomial process. Although these simplifications ignore some of the elegant technical sophistication of their model, they retain its spirit and, I believe, help pinpoint the intuitive economic content of the analysis.

Consider a one-period problem in which the individual chooses preventive expenditures Z and insurance I to maximize

$$Eu = (1-p)u(Y_0 - \rho I - Z) + pu(Y_1 + xI) \qquad (1)$$

In this formulation $u(\cdot)$ is the utility function (assuming risk aversion), p is the probability of a "standard" illness, Y_0 is income if illness doesn't occur, Y_1 is net income if illness does occur [$(Y_0 - Y_1)$ is the medical bill], ρ is the price of insurance, and xI is the amount of medical bills paid by the insurance company. Assume that p is a function of preventive expenditure, $p(Z)$, with

$dp/dz = p' < 0$ so that preventive medicine is productive. The marginal conditions for a maximum of (1) subject to $p(Z)$ are

(2) $$\partial Eu/\partial I = -(1-p)\rho u_0' + xpu_1' = 0$$

(3) $$\partial Eu/\partial p = -p'(u_0 - u_1) - (1-p)u_0' = 0$$

where u_0' is shorthand for marginal utility evaluated at the appropriate value of non-illness net income and u_1' is marginal utility evaluated at the appropriate value of illness net income, and similarly for u_0 and u_1.

Just as in Nordquist and Wu's more sophisticated model, the content of this theory is obtained by differentiating the marginal conditions with respect to exogenous parameters and exploiting second-order conditions, as usual. A geometrical interpretation can be given in the present case by using the indirect utility function. We want to derive indifference curves between Z and p conditional on the individual's buying the optimum amount of insurance coverage at every value of p. Condition (2) above defines the optimum amount of insurance for all values of p. If the functional form of u were given, (2) could be solved for I in terms of p, Z, and the other variables and substituted into (1), resulting in a synthetic, indirect utility function relating Eu to p, Z, Y_0, Y_1, ρ, and x. Values of I are "optimized out" as it were. If a specific functional form is not given, the indirect utility function is defined only implicitly by equations (1) and (2). In other words, ignore (3) for the moment and treat (1) and (2) as two equations in which I and Z are considered to be dependent variables and p, Eu, x, ρ, Y_1 and Y_0 are considered to be independent variables. Then the function $Z(p, Eu, \ldots)$ implicitly defined by (1) and (2) yields a family of indifference curves between Z and p at alternative values of Eu.[1] In distinction to the usual case, the entire indifference map relating Z and p shifts when x, ρ, Y_1, and Y_0 change, because in each case the optimum amount of insurance changes.

The implicit function theorem applied to (1) and (2) establishes all the essential properties of $Z(p, Eu, \ldots)$. In particular it readily shows that $\partial Z/\partial Eu$, $\partial Z/\partial p$, and $\partial^2 Z/\partial p^2$ are all negative. Therefore, the indifference curves appear as E_0, E_1, and E_2 in Figure 1. Since Z and p are "bads," it should come as no surprise that the indifference curves are concave and expected utility rises as we move toward the origin. The constraint relating preventive medical expenditure and the probability of illness is shown in Figure 1 as the curve labeled $p(Z)$. Hence the optimum amount of self-protection and resulting probability of illness occur as usual at a point of tangency between an indifference curve and the constraint. Since $\partial Z/\partial p = -(u_0 - u_1)/(1-p)u_0'$ along an indifference curve, the geometry and Condition (3) are internally consistent.

Think of the slope of an indifference curve, $-\partial Z(p, Eu, \ldots)/\partial p$, as a reservation price. It is the (incremental) amount the individual is willing to pay to reduce medical risk by a small amount. The theory of utility maximization and risk aversion places no restrictions on how reservation prices vary with the level of welfare, Eu (i.e., the derivative $\partial^2 Z/\partial p \partial Eu$ is unsigned and could be either positive or negative). This is the fundamental reason why Nordquist and Wu get so few positive predictions from their theory. Income effects resulting from parameter changes can go in either direction, and even if substitution effects are unambiguous, the total, uncompensated effects are not. Thus, to get unambiguous predictions it is necessary to make a *priori* assumptions about the sign of income effects. To capture the essence of their crucial assumptions in the present simplified model, assume that the marginal reservation price of medical risk falls with real income. Then the slopes of the indifference curves in Figure 1 become steeper as we move up any vertical line. I find it difficult to say whether such an assumption is "reasonable" or not. Perhaps it is equally plausible to assume that the amount a person will pay to reduce medical risk increases with wealth instead of decreasing. Here would seem to be a case where ignoring pain and suffering might make a difference. Whatever, let us examine the implications of this kind of assumption.

Suppose that the price of insurance, ρ, decreases. Repeated application of the implicit function theorem to the definition of the indifference map (equations (1) and (2)) has two implications. First, the entire indifference map shifts up ($\partial Z\ (p, Eu, \ldots)/\partial \rho$ is negative) and the individual is unambiguously better off at the new equilibrium. Second, the new indifference curves are not so sharply inclined as the old ones were ($\partial^2 Z/\partial p\, \partial \rho$ is negative): The compensated marginal offer price-risk *schedule* for reductions in medical risk shifts downward. Now without some a *priori* specification of the income effect, the net outcome in the new situation could involve either more or less risk than the old one. However, if reservation prices fall with increases in Eu, the new equilibrium must be at a point on $p\,(Z)$ such as B. Preventive expenditure falls, real risks rise, and there is a clear case of moral hazard.

Consider next an increase in x, the share of medical remedy costs reimbursed by market insurance. Again the indifference curves shift upward and the individual must be better off at the new equilibrium. But in this case it turns out that the simple theory does not provide an unambiguous prediction about what happens to the reservation price (i.e., $\partial^2 Z/\partial p\, \partial x$ is unsigned). There is only a presumption that the indifference map tilts in the same way as it did for the above case of a decrease in ρ. If it does, we get the same kind of outcome; a move to the new equilibrium at a point such as B, a decrease in Z, and an increase in p and moral hazard.

This simple theory by itself is silent about both income and substitution effects for changes in x, whereas for changes in ρ it does make an unambiguous prediction about substitution effects, but of course not about income effects.[2] Nordquist and Wu get a similar result in their more sophisticated model, except that the substitution effect is definitely signed for changes in x but not for changes in ρ (see their equations (8.2) and (9.2)).

Finally, consider a change in the risk-expenditure constraint $p\,(Z)$. In fact, suppose that $p\,(Z)$ simply shifts to the left in Figure 1 without changing its slope, a pure income effect, owing, for example, to an increase in public health. In this case we get a very puzzling result if the same income effect assumption as above is maintained: As long as the new equilibrium is interior, preventive care falls and real risks rise. Of course, it is possible that the shift in $p\,(Z)$ is so large that the new equilibrium occurs along the p axis, in which case Z falls to zero and p definitely decreases. But for marginal changes, the above assumption about income effects implies that slight improvements in public health induce individuals to expose themselves to greater risks. There is more illness after the improvement than before! This outcome does not appear very "reasonable" to me at all, but then again it is only a product of the assumption and not necessarily an implication of the pure theory.[3]

In sum, the theory presented by Nordquist and Wu contains very few empirical predictions. Given the technical sophistication of their model, it seems doubtful whether further theorizing will result in a more authoritative theory. Clearly, here is a case in which careful empirical study is the next order of business. This theory is useful for organizing the structural relations to be estimated from data and for clarifying thought. But it does not give much guidance in advance about what these relationships should look like.

NOTES

1. Alternatively, p and l can be treated as "dependent" and Z, Eu, x, p, Y_1, and Y_2 as "independent" variables, yielding a function $p(Z, Eu, \ldots,)$. Of course, $p(Z; \ldots)$ is simply the inverse of $Z(p; \ldots)$ and contains the same information about the indifference map.
2. To keep within the spirit of Nordquist and Wu's model, notice that Z is not subtracted from $Y_1 + xl$ in Equation (1). In the context of a straight one-period model, it makes some sense for Z to be subtracted from income in both states. The conceptual basis of the diagrammatic exposition in Figure 1 is unchanged in that case, but my cursory examination of it shows analysis is much more difficult: It is not even clear that the indifference curves can be shown to be concave. If so, then not even many of the pure substitution effects can be signed.
3. Improvements in public health must change insurance premiums and affect the result. I have ignored these general equilibrium repercussions because Nordquist and Wu ignored them.