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by
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ABSTRACT

This paper analyses the effects of uncertainty on the demand for medical care. It employs a simplified version of Grossman's human capital model of the demand for health to examine the consequences for the demand for medical care of increased uncertainty surrounding the effectiveness of medical treatment and the incidence of ill-health. We show that under plausible assumptions the demand for medical care will increase following increased uncertainty over the incidence of ill-health. We also show that though the effects of increased uncertainty over the effectiveness of medical care are indeterminate *a prion*, it is possible to identify situations in which one can make unambiguous predictions about how the demand for medical care responds to increased uncertainty over the effectiveness of medical care. In addition to presenting the comparative static results, we also discuss their policy implications.

1. Introduction

The pervasiveness of uncertainty in the field of medical care has long since been recognized. Indeed, Arrow (1963) went so far as to suggest that "virtually all the special features of ... [the medical care] industry stem from the prevalence of uncertainty" (Arrow, 1963, p.946). Though many today would probably stop short of this conclusion, few would quarrel with Arrow's claim that the uncertainty surrounding medical care is possibly more intense than in most other commodities.

In view of this it is somewhat surprising that there has been so little positive analysis of the implications of uncertainty for the demand for medical care services. Though there have been several theoretical analyses of the demand for medical care in an uncertain environment, none of these studies have explored the consequences of increased uncertainty for the demand for medical care. In this paper we examine the effects of uncertainty on the demand for medical care using a simplified version of Grossman's (1972a, b) human capital model of the demand for health. We examine both types of uncertainty identified by Arrow (1963), namely the uncertainty surrounding the effectiveness of medical treatment and the uncertainty surrounding the incidence of illness. In analysing the effects of increased uncertainty we adopt the characterization of increased risk proposed by Rothschild and Stiglitz (1970). This is a more interesting comparative static exercise than the analysis of the effects of an increase in the mean of the relevant random variable. It is this latter approach that has been employed in the only studies to date in the area. As well as presenting our comparative static results, we also discuss some of their policy implications.

The paper is organized as follows. Section 2 provides a brief survey of the previous literature in the area. Section 3 outlines our model and discusses some of its relevant properties in the case of perfect certainty. The next section - Section 4 - presents the comparative static results relating to the uncertainty version of our model. The final section - Section 5 - contains a summary of the main points to emerge from the paper.

2. The Previous Literature

Formal models of the demand for medical care can be divided into two groups. Models in the first are characterized by the assumption that it is the patient who is the demander of medical care services, whilst in models in the second group it is the physician who demands medical care on behalf of his patient. As Muurinen (1982a) has emphasized, it is probably wrong to view these two approaches as rival hypotheses, since each is undoubtedly partially true. Certainly the decision to consult a physician in the first instance rests with the patient. It may also be the case, as Muurinen suggests, that the patient forms some view as to an appropriate level of consumption for his particular set of symptoms. The role of the physician then becomes one of determining an appropriate treatment mix and possibly adjusting the overall level of consumption upwards or downwards in the light of his own (more expert) diagnosis.[1] Though consumer sovereignty models are undoubtedly incomplete, they ought, therefore, at least to be able to shed <u>some</u> light on the determinants of the demand for medical care. It is this type of model with which we are concerned in this paper.

Early consumer sovereignty models of the demand for medical care viewed medical care as a direct source of utility. Following the seminal work of Grossman (1972a, b), however, it has become customary to view the

demand for medical care as being derived from the demand for a more fundamental "commodity", namely health itself. Medical care then becomes one of the "factors of production" used in the "production" of health. In these "demand-for-health" models it is common to distinguish between the stock of the commodity "health" and the flow of "services" derived therefrom. The latter are typically defined in terms of "healthy time" and are assumed to affect the individual's utility directly (ill-health is in itself unpleasant) and indirectly (via its impact on labour income). Frequently models in the demand-for-health genre are set in the context of the lifecycle, with "health" being treated as a durable commodity which is subject to depreciation but which is capable of being increased by acts of investment.[2]

There are two alternative ways in which uncertainty can be introduced into these models. The first is to introduce randomness into the equation determining the individual's level of health. This was the approach adopted by Grossman (1972a), who suggested treating the depreciation rate of health "capital" as stochastic rather than deterministic. Though Grossman did report some results obtained using state-preference theory, the implications of uncertainty were not fully explored. Phelps (1973) provided a more complete analysis of Grossman's (1972a,b) model under uncertainty. In Phelps's model, the individual's level of health is specified as the sum of (i) his initial health, (ii) a random variable representing random health losses and (iii) the production of new health. In his comparative static analysis Phelps considered the effects of a ceteris paribus change in the mean of the distribution of the random health loss variable: he did not, however, analyse the effects of a ceteris paribus change in its riskiness. The effects of increases in uncertainty on the demand for medical care were therefore left unexplored.[3]

The second approach to modelling uncertainty in models of the demand for health is to introduce randomness into the relationship between health and the "services" derived from health. This is the approach adopted by Cropper (1977), who developed a model in which high stocks of health capital reduce the probability of illness occuring but do not guarantee its non-occurence. She showed that persons who have a relatively high probability of becoming ill for a given stock of health capital will purchase more (preventive) medical care than will persons with a relatively low probability of beoming ill. She did not, however, analyse the effects of increased uncertainty about the probability of becoming ill.

Two main conclusions emerge from the above. First, comparative static results relating to random varibles have only been obtained for ceteris paribus changes in the mean of the variable in question. The effects of increased uncertainty have not been explored. Second, the only type of uncertainty examined to date has been the uncertainty surrounding the incidence of illness. In none of the studies to date has the uncertainty surrounding the effectiveness of medical care been analysed. The remainder of the paper is devoted to an exploration of the effects of increases in both types of uncertainty on the demand for medical care.

3. The Model and its Properties Under Certainty

Tokeep the analysis simple, we base our model on Wagstaff's (1986a) simplified version of Grossman's (1972a,b) "pure-consumption" model. The simplified model affords most of the insights of Grossman's more complex model but is considerably more tractable.

The individual is assumed to derive utility according to the Neumann-Morgenstern utility function U(C,H), where C denotes consumption and H is the commodity "health". U(.) is assumed to be continuous, increasing and concave in both C and H, and at least three times continously differentiable. Health is produced by medical care (and, in principle, other market goods, such as nutritious food) according to the health production function, H(M), where M is medical care. We assume H(.) to be linear and of the form

$$(1) \quad H = a + b\,M,$$

where a can be interpreted as the basic level of health and b as the marginal (and average) product of medical care. In section 4, we let a and b be random variables; at present they are assumed to be (positive) constants. The final component of the model is the budget constraint,

$$(2) \quad Y = P_c C + P_m M,$$

where Y is income, P_c is the price of consumption and P_m the price of medical care. Letting $P_c = 1$, (2) can be rewritten as

$$(2') \quad C = Y - P_m M.$$

The individual's problem can be stated

$$(3) \quad \begin{array}{ll} \underset{M}{\text{Max}} & U(Y - P_m M,\ a + bM) \\ \text{st} & Y > M > -\dfrac{a}{b} \\ & \quad P_m \end{array}$$

The two inequality constraints ensure C, H > 0. The necessary and sufficient conditions for an interior maximum to this problem are

$$(4) \quad -P_m U_1 (Y - P_m\hat{M}, a + b\hat{M}) + bU_2 (Y - \hat{P}_m M, a + b\hat{M}) = 0$$

$$(5) \quad D = P_m^2 U_{11} - 2P_m b U_{12} + b^2 U_{22} < 0$$

where $\hat{M}$ denotes the optimal value of M, D is negative by concavity of U(.) and U_1 (for example) denotes $\partial U(.)/\partial C$. Equation (4) can be rewritten as

$$(4') \quad U_1(.)/U_2(.) = b/P_m,$$

which states that in equilibrium the marginal rate of substitution between health and consumption equals the "shadow price of health", b/P_m.

For the analysis of the uncertainty version of the model, it will be useful to have the predictions of the model relating to changes in the parameters a and b. The effect of an increase in a on $\hat{M}$ is found by implicit differentiation of (4) with respect to a: thus

$$(6) \quad \partial\hat{M}/\partial a = -(1/D)[-P_m U_{12} + b U_{22}],$$

which cannot be signed <u>a priori</u> without further restrictions on U(.). It is easily shown[4], however, that if C is a normal good, $-P_m U_{12} + bU_{22} < 0$. Hence, given that D is negative from (5), $\partial\hat{M}/\partial a < 0$. Thus an increase in the basic level of health results in a reduction in the demand for medical care. This is because the individual requires a smaller quantity of medical care to obtain a given level of health.

The effect of a change in b is found by implicit differentiation of

(4) with respect to b : thus

$$(7) \quad \partial\hat{M}/\partial b = \hat{M}(\partial M/\partial a) - (1/D)\, U_2.$$

The first term on the right hand side can be interpreted as an income effect and the second as a substitution effect. Since $\hat{M} > 0$ and $\partial\hat{M}/\partial a$ is negative, the income effect is negative. The intuition behind this is the same as for the case above: i.e. when b increases, the individual needs to consume less medical care to obtain the same level of health. This therefore encourages him to consume less medical care. The substitution effect, however, is positive. This is because a reduction in b implies a reduction in the shadow price of health, so that the individual is encouraged to substitute health for consumption. The net effect of those two counteracting forces is indeterminate a priori. However, one might reasonably expect the relationship between $\hat{M}$ and b to be backward bending. For sufficiently small values of b, $\hat{M}$ will be sufficiently small for the income effect to be dominated by the substitution effect, so that $\partial\hat{M}/\partial b$ will be positive. For large values of b, $\hat{M}$ may become sufficiently large for the income effect to dominate the substitution effect.[5]

4. The Model Under Uncertainty

In this section we consider the comparative static results of the model when uncertainty is introduced. Specifically, we let the basic level of health and then the marginal product of medical care become random variables: randomness in the former captures the uncertainty surrounding the incidence of ill-health, whilst randomness in the latter captures the uncertainty surrounding the effectiveness of medical care.

4.1 Uncertainty surrounding the basic level of health

To analyse the case where there is uncertainty surrounding the basic level of health, we assume that b is known with certainty, but that a is the mean of a random variable A. Thus in contrast to the situation in the model of the previous section, the individual is now uncertain what his basic level of health will be. The variable A is assumed to have a cumulative distribution F(A), with support lying in the interval $|\underline{A}, \bar{A}|$, with $\underline{A} > 0$. The individual's problem then becomes

$$\text{(8)} \qquad \begin{array}{l} \underset{M}{\text{Max}} \quad U(Y - P_m M,\ A + bM)\, dF(A) \\ \text{st} \quad Y > M > -(\underline{A}/b). \\ \qquad\ \ P_m \end{array}$$

The inequality constraints ensure that both C and H are positive with a probability equal to one. Necessary and sufficient conditions for an interior maximum are

$$\text{(9)} \quad -P_m E[U_1(Y - P_m M^*,\ A + bM^*)] + bE[U_2(Y - P_m M^*,\ A + bM^*)] = 0,$$

$$\text{(10)} \quad K \equiv E[P_m^2 U_{11} - 2P_m b U_{12} + b^2 U_{22}] < 0,$$

where the mathematical expectation is taken with respect to the distribution of A and M^* is the optimal value of M for problem (8).

It is easily verified that $\partial M^*/\partial a$ - i.e. the effect of a bodily rightward shift in the distribution of A - has the same sign as $\partial \hat{M}/\partial a$ in equation (6) (cf. e.g. Hey, 1981, p.38). Thus an increase in the expected basic level of health results in a reduction in medical care consumption. This is the same result as obtained by Phelps (1973) and accords with

intuition. This result is of some interest from a policy perspective. It suggests that if the expected basic level of health of the population tends to increase over time as environmental conditions improve, there will ceteris paribus be a tendecy for medical care consumption to fall over time.[6]

Consider next the effects of increased uncertainty about the basic level of health. To do this we examine the effects of a mean-preserving spread in tne distribution of A of the type proposed by Rothschild and Stiglitz (1970). We denote the family of cumulative distribution functions of A by $F(A, \rho)$, where ρ is a riskiness parameter and use F_ρ to denote a small change in the distibution of A. Following Diamond and Stiglitz (1974), an increase in ρ constitutes a mean-preserving spread of the distribution of A if and only if the following two conditions hold:

$$(11) \quad \int_{\underline{A}}^{\bar{A}} F_\rho(A, \rho)\, dA = 0,$$

$$(12) \quad \int_{\underline{A}}^{\theta} F(A, \rho)\, dA \geq 0 \quad \forall\, \theta \in |\underline{A}, \bar{A}|.$$

The effect of a Rothschild-Stiglitz - hereafter RS - increase in risk on the optimal value of M can be determined by implicit differentiation of (9) with respect to ρ. In Proposition 1 in the Appendix we show that

$$(13) \quad \text{sign}\,[\partial M^*/\partial\rho] = \text{sign}\,[(-P_m U_{122} + a\, U_{222}].$$

If U(.) is additively separable (so that $U_{122} = 0$), the assumption of decreasing absolute risk aversion with respect to H is sufficient to sign $\partial M^*/\partial\rho$: in this case $\partial M^*/\partial\rho > 0$, so that the demand for medical care increases as uncertainty about the basic level of health increases.

Though strong separability is often invoked in empirical work in this area (see e.g. Muurinen, 1982c; Wagstaff, 1986b), it is a highly restrictive assumption (cf. e.g. Deaton and Muellbauer, 1980, pp. 137-139). If U(.) is not assumed to be additively separable, $\partial M^*/\partial b$ can only be signed if some assumptions are made about the two-good absolute risk aversion index

$$(14)\quad R^A = - U_{22}(.)/U_2(.).$$

We make the intuitively plausible assumption that R^A is non-increasing in M. This assumption, together with our earlier assumption that $-U_{12} + bU_{22} < 0$, is sufficient to sign $\partial M^*/\partial \rho$ when U(.) is non-separable. In Proposition 2 in the Appendix we show that if these assumptions are satisfied, the demand for medical care will increase in response to increased uncertainty over the basic level of health. This result accords well with intuition. One would expect the individual to demand some medical care as a precaution against the possibility of a low value of H. When the uncertainty surrounding the basic level of health increases, one would expect the consumer to increase this "precautionary" component of his medical care consumption. The intuition behind the two assumptions required to produce this result is, perhaps, less obvious and may be explained as follows. When the uncertainty over A increases, the individual perceives this as equivalent to a reduction in the mean of A. Providing C is a normal good, this encourages the individual to consume more medical care (cf. equation (6) above). This is, however, only one part of the story: because the individual becomes decreasingly risk averse as his medical care consumption increases, by consuming more medical care he reduces his perceived risk of the outcome. This second effect, like the first, therefore tends to encourage an increase in medical care consumption. As a

result, the sign of $\partial M^*/\partial \rho$ is unambiguously positive.

From a policy perspective this result suggests that policy measures which result in a reduction in the extent of uncertainty over the basic level of health will tend to result in reductions in medical care consumption. One example of such a policy measure is a health education programme. As individuals became better informed about the risks of developing different conditions, so their uncertainty about their basic level of health will be reduced. A health education programme would therefore be expected to result in reduced levels of "precautionary" medical care consumption. Since the precautionary component of medical care consumption is strictly-speaking "unecessary", this consequence of a health education programme would presumably be viewed as desirable.

4.2 Uncertainty surrounding the effectiveness of medical care

To analyse the case where there is uncertainty about the effectiveness of medical care we assume that A is certain and equal to its expected value a, but b is the mean of a random variable B. Specifically, we assume that B is a random variable with cumulative distribution G(B) and support that lies in the interval $|\underline{B}, \bar{B}|$, with $\underline{B} > 0$. The individual's problem is now

$$\begin{aligned} &\underset{M}{\text{Max}} \quad \int Y(Y - P_m M,\ a + BM)\, dG(B) \\ &\text{st} \quad \frac{Y}{P_m} > M > -(a/B). \end{aligned} \tag{15}$$

The inequality constraints ensure that $C, H > 0$ with probability one. Necessary and sufficient conditions for an interior maximum are

$$(16) \quad -P_m E[U_1(Y - P_m\tilde{M}, a + B\tilde{M}) + E[U_2(Y - P_m\tilde{M}, a + B\tilde{M})] = 0,$$

$$(17) \quad L \equiv E[P_m U_{11} - BP_m U_{12} + B^2 U_{22}] < 0,$$

where the expectation is now taken with respect to the distribution of B, and $\tilde{M}$ is the optimal value of M for problem (15).

It may be verified that the sign of $\partial\tilde{M}/\partial b$ - i.e. the effect of a bodily rightword shift in the distribution of A - has the same sign as $\partial\hat{M}/\partial b$ in equation (7). Thus the effect of an increase in the expected effectiveness of medical care cannot be signed a priori. The intuition behind this result is the same as that in the certainty case considered in section 3. This result is also of some interest from a policy perspective. It suggests that, contrary to what is often assumed (see e.g. Feldstein, 1971), a tendency for the expected effectiveness of medical care to increase over time need not necessarily result in continuously rising demand for medical care services.

The effect of an increase in uncertainty over the effectiveness of medical care can be found using the same technique as in section 4.1. In Proposition 3 in the Appendix we show that

$$(18) \quad \text{sign}\,[\partial\tilde{M}/\rho] = \text{sign}\,[\tilde{M}^2(-P_m U_{122} + BU_{222}) + 2\tilde{M}U_{22}].$$

The right hand side of (18) consists of two terms: the first might be termed the "uncertainty income effect", because its sign is the same as that of (13), and the second the "uncertainty substitution effect". The latter is negative if the individual is risk averse - i.e. $U_{22} < 0$. The "uncertainty income effect" is, as has been seen, positive if R^A is non-

decreasing in M and $- P_m U_{12} + bU_{22} < 0$. Thus in contrast to the case discussed in section 4.1 above, the net effect of an increase in uncertainty in this case is ambiguous. The reasons for this ambiguity are twofold: (i) From the certainty case we know that the effect of an change in the mean of B is ambiguous; (ii) In the case of uncertainty over the basic level of health, the individual may hedge against uncertainty by increasing the expected value of H without affecting higher moments. In the case where the uncertainty relates to the effectiveness of medical care, an increase in the consumption of medical care raises both the expected value of H and its variability. The net outcome of these two counteracting forces cannot be determined a priori.

Using some results obtained by Dardanoni (1986) it is possible, however, to be more specific about the consequences of greater uncertainty surrounding the effectiveness of medical care. From the discussion of the previous case it would seem plausible that the sign of $\partial \tilde{M}/\partial \rho$ will depend in part on the individual's attitude towards risk. In Proposition 4 in the Appendix we show that the sign of $\partial \tilde{M}/\partial \rho$ depends on the behaviour of the two-good index of proportional risk aversion[7]

$$(19)\quad R^P = -BM[U_{22}(.)/U_2(.)]$$

as the level of medical care consumption changes, but also on the sign of $\partial \tilde{M}/\partial b$. In particular, if $\partial \tilde{M}/\partial b$ is negative (positive) and R^P is non-increasing (non-decreasing) in M, then $\partial \tilde{M}/\partial \rho$ is positive (negative). The intuition behind this result mirrors that of the case considered in section 4.1. An increase in the risk of the distribution of B is perceived as akin to a reduction in its expected value. If the individual increases (decreases) his consumption of medical care when b decreases and in so

doing considers that he is exposing himself to less risk, then $\partial\tilde{M}/\partial\rho$ will definitely be positive (negative).

Though this result is helpful in that it clarifies the nature of the various forces at work is bringing about changes in the consumer's demand for medical care, its usefulness is somewhat limited. This is because, in contrast to the case considered above, it is not possible to obtain an unambiguous prediction in this instance by making plausible assumptions about the nature of the individual's utility function. It is not clear a priori whether $\partial\tilde{M}/\partial b$ is in general likely to be negative or positive; nor is it clear whether R^p is in general likely to be increasing or decreasing in M. There are good grounds for supposing, however, that for sufficiently small values of M, both $\partial\tilde{M}/\partial b$ and $\partial R^p/\partial M$ will both be positive, so that $\partial M/\partial\rho$ will be negative. We have already argued in section 3 that it seems plausible to expect the relationship between M and b to be backward-bending: thus for sufficiently small M, $\partial\tilde{M}/\partial b$ will probably be positive. There are also good reasons for supposing that for sufficiently small values of M the proportional risk aversion index, R^p, will be increasing in M.[8] For small values of M, therefore, the sign of $\partial\tilde{M}/\partial\rho$ will probably be negative.

This result also seems intuitively plausible. Individuals consuming small quantities of medical care will, if the health is a normal good, tend to be those on low incomes. When the uncertainty surrounding the effectiveness of medical care increases, these individuals can ill afford to spend so much of their income on the risky commodity. They therefore substitute towards the (riskless) consumption commodity and reduce their consumption of (risky) medical care. Individuals with higher incomes might, however, choose to consume more medical care, since by doing so, they increase the expected value of H and can better "afford" to reduce

their level of consumption and expose themselves to the greater risk this entails.

The results above suggest that policy measures which result in a reduction in the uncertainty surrounding the effectiveness of medical care may cause medical care consumption to rise or fall. Among low income groups it is probably more likely that it will increase. Thus measures aimed at reducing the variation in the competence and quality of physicians, for example, will probably cause medical care consumption to increase amongst low income groups. In general, though, the effects of such a policy measure are indeterminate a priori.

5. Summary

In view of the pervasiveness of uncertainty in medical care, it is surprising that so little research effort has been directed at analysing the consequences of uncertainty for the demand for medical care services. Though Grossman's (1972 a,b) model of the demand for health has been extended to an uncertain environment by Phelps (1973) and Cropper (1977), in neither study were the effects of uncertainty on the demand for medical care analysed.

This paper employs the simplified Grossman model of Wagstaff (1986a) to analyse the implications for the demand for medical care of uncertainty surrounding both the effectiveness of medical care and the incidence of ill-health. We show that under plausible assumptions the individual will reduce his demand for medical care in response to an increase his expected "basic" level of health. Thus if the basic level of health of the population tends to increase over time as environmental conditions improve,

there will, ceteris paribus, be a tendency for medical care consumption to fall over time. We also show that if the two-good absolute risk aversion index is non-increasing in medical care consumption, the individual will increase his demand for medical care in response to an increase in uncertainty about his basic level of health. Policy measures such as health education programmes which result in individuals becoming better informed about the risks of acquiring different diseases ought, therefore, to result in a reduction in the demand for medical care. Another result that is of some interest from a policy perspective is that the effect of an increase in the expected effectiveness of medical care on the demand for medical care cannot be signed a prior. This means that, contrary to what is often assumed, a tendency for the expected effectiveness of medical care to increase over time need not necessarily result in a continuously rising demand for medical care. What can be said, however, is that an increase in the expected effectiveness of medical care is likely to lead to increased medical care consumption amongst low-income groups. The effect on the demand for medical care of an increase in the uncertainty surrounding the effectiveness of medical care is also found to be indeterminate a priori. Thus measures aimed at reducing the variation in the competence and quality of physicians, for example, may cause medical care consumption to rise or fall. There is good reason to suppose,however,that - at least amongst those in low income groups - the demand for medical care will fall, since individuals on low incomes will have a greater incentive to substitute away from the risky commodity (medical care) towards the riskless commodity (other consumption).

Footnotes

1. Many would argue that the physician can exploit his superior knowledge to "create" demand for his services, so that the final bundle of services selected will also reflect the physician's own preferences and constraints (cf. e.g. Evans, 1974).

2. Examples of formal models of the demand for health include those of Grossman (1972a,b) and Muurinen (1982b).

3. A similar model has been employed by Pauly (1980) and van Doorslaer (1985) to analyse the demand for therapeutic information.

4. Rewrite (3) as

$$\underset{C}{\text{Max}} \; U(C, a + b\,(Y - C)/P_m$$

Differentiating the resultant first-order condition, it emerges that

$$\text{sign} \; (\hat{C}/Y) = \text{sign}\,(P_m U_{12} - bU_{22})$$

where $\hat{C}$ is the optimal value of C.

5. Our model is formally equivalent to the textbook consumption-leisure model where the analogue of $\partial M/\partial b$ is the partial derivative of labour supply with respect to the wage rate (cf Dardanoni, 1986).

6. In practice, of course, though there has been a secular increase in the basic level of health, medical care consumption has also increased. This is not necessarily inconsistent with the predictions of our model, however, since a whole variety of other factors have

been changing simultaneously: incomes have been rising and life expectancy has increased.

7. The index of proportional risk aversion for one argument utility functions was introduced by Menezes and Hanson (1971) and Zeckhauser and Keeler (1971).

8. It is easy to show that Arrow's (1971) hypothesis of increasing relative risk aversion implies that the proportional risk aversion index is also increasing. Moreover, a heuristic argument that for sufficiently small values of M the index $R^p(M,a) = -MB\,U_{22}(\,,\,)/U_2(\,,\,)$ is likely to be increasing in M is as follows. For a risk averse individual, $R^p > 0$ if M and B are non-negative. However, $R^p(0,a) = 0$ if U_{22} and U_2 are bounded, so that in a neighbourhood of $M = 0$, R^p will be increasing in M.

Appendix

In this appendix we prove the results stated in eq.s (13) and (18).

Proposition 1 The sign of $\partial M^*/\partial\rho$ is the same as the sign of $(-P_m U_{122} + bU_{222})$.

Proof Implicit differentiation of (9) with respect to ρ yields

$$(A1) \quad \partial M^*/\partial\rho = -(1/K) \left\{\int_{\underline{A}}^{\bar{A}} (bU_2 - P_m U_1)\, dF_\rho\right\}$$

Integrating the term in curly brackets by parts twice, using $F_\rho(\underline{A},\rho) = F_\rho(\bar{A},\rho) = 0$ and (11), yields

$$(A2) \quad \int_{\underline{A}}^{\bar{A}} (bU_2 - P_m U_1)\, dF_\rho = -\int_{\underline{A}}^{\bar{A}} (bU_{22} - P_m U_{12})\, F_\rho dA$$

$$(A2') \quad = \int_{\underline{A}}^{\bar{A}} (bU_{222} - P_m U_{122}) \left[\int_{\underline{A}}^{\bar{A}} F_\rho(t,\rho)dt\right]dA$$

The term inside the square brackets in (A2') is non-negative from (12), so that - given $K < 0$ - the sign of $\partial M^*/\partial\rho$ is the same as the sign of $(bU_{222} - P_m U_{122})$. Q.E.D.

Proposition 2 M^* increases for mean-preserving increases in risk in the distribution of A.

Proof Differentiate R^A with respect to M to give

$$(A3)\quad \frac{\partial R^A}{\partial M} = \frac{(P_m U_{122} - bU_{222})U_2 - U_{22}(P_m U_{12} - bU_{22})}{(U_2)^2} \leq 0$$

given continuity of U(.). Assuming C is normal, so that $P_m U_{12} - bU_{22} > 0$, $(P_m U_{122} - bU_{222})$ must be negative to satisfy (A3). Using (13), the result follows immediately. Q.E.D.

Proposition 3 The sign of $\partial \tilde{M}/\partial\rho$ is the same as the sign of $[\tilde{M}^2(-U_{122} + BU_{222}) + 2\tilde{M}U_{22}]$.

Proof Implicit differentiation of (16) with respect to ρ yields

$$(A4)\quad \partial\tilde{M}/\partial\rho = -(1/L)\left\{\int_{\underline{B}}^{\bar{B}} (BU_2 - P_m U_1)\, dG_\rho\right\}$$

Integrating the term in curly brackets by parts twice and using the R-S characterization of a mean-preserving spread of the distribution $G(B,\rho)$, we have

$$(A5)\quad \int_{\underline{B}}^{\bar{B}} (BU_2 - P_m U_1)\, dG_\rho = -\int_{\underline{B}}^{\bar{B}} (P_m\tilde{M}U_{12} - \tilde{M}BU_{22} + U_2)\, G_\rho dB$$

$$(A5')\quad = \int_{\underline{B}}^{\bar{B}} [\tilde{M}^2(-P_m U_{122} + BU_{222}) + 2\tilde{M}U_{22}] \left[\int_{\underline{B}}^{\bar{B}} G_\rho(t,\rho)\, dt\right] dB$$

The term inside the second pair of square brackets in (A5') is non-negative from (12). Given $L < 0$, the result follows immediately. Q.E.D.

Proposition 4 If $\partial\hat{M}/\partial$ is negative (positive) and R^P is non-increasing (non-decreasing) in M, then $\partial\tilde{M}/\partial\rho$ is positive (negative).

Proof Differentiating R^P with respect to M yields

$$(A6) \quad \frac{\partial R^P}{\partial M} = \frac{[-BU_{22} + BM(P_mU_{122} - BU_{222})]U_2 + BMU_{22}(BU_{22} - P_mU_{12})}{(U_2)^2}$$

given continuity of U(.). Rearranging (A6) gives

$$(A6') \quad \text{sign}(\partial R^P/\partial M) = \text{sign}\left\{ -U_{22}M\left[1 - \frac{M(BU_{22} - P_mU_{12})}{U_2}\right] - M^2(BU_{222} - P_mU_{122}) \right\}$$

From (7)

$$(A7) \quad \text{sign}(\partial \hat{M}/\partial b) = \text{sign}\left[\frac{M(BU_{22} - P_mU_{12})}{U_2} + 1\right]$$

Consider the case when $\partial \hat{M}/\partial b < 0$ and R^P is non-increasing in M. From (A6') $\partial R^P/\partial M \leqslant 0$ implies

$$(A8) \quad -U_{22}M\left[1 - \frac{M(BU_{22} - P_mU_{12})}{U_2}\right] \leqslant M^2(BU_{222} - P_mU_{122})$$

From (A7) $\partial \hat{M}/\partial b < 0$ implies

$$\left[1 - \frac{M(BU_{22} - P_mU_{12})}{U_2}\right] > 2$$

$$\Rightarrow -U_{22}M\left[1 - \frac{M(BU_{22} - P_mU_{12})}{U_2}\right] > -2MU_{22}$$

This result and (A8) together give

$$-2MU_{22} - M^2(BU_{222} - P_m U_{122}) < - U_{22}M \left[1 - \frac{M(BU_{22} - P_m U_{12})}{U_2}\right] \leq 0$$

so that $[2MU_{22} + M^2(BU_{222} - P_m U_{122})] \geq 0$ and $\partial \tilde{M}/\partial \rho > 0$ by Proposition 3. The result for the case where $\partial \hat{M}/\partial b > 0$ and $\partial R^P/\partial M \geq 0$ follows immediately by reversing the inequalities in the above. Q.E.D.

References

Arrow, K.H. (1963). Uncertainty and the welfare economics of medical care, American Economic Review, 53, 941-73.

Arrow, K.H. (1971) Essays in the Theory of Risk Bearing (Markham, Chicago).

Cropper, M.L. (1977). Health, investment in health and occupational choice, Journal of Political Economy, 85, 1273-94.

Dardanoni, V. (1986). Optimal choices under uncertainty: the case of two-argument utility functions, Mimeo, Department of Economics and Related Studies, University of York.

Diamond, P.A. and J.E. Stiglitz (1974). Increases in risk and risk aversion, Journal of Economic Theory, 8, 3347-60.

Deaton, A. and J. Muellbauer (1980). Economics and Consumer Behaviour (Cambridge University Press, Cambridge).

Evans, R.G. (1974). Supplier-induced demand: some empirical evidence and implications, in M. Perlman, ed., The Economics of Helath and Medical Care (MacMillan, London).

Feldstein, M.S. (1971). Hospital cost inflation: a study of nonprofit price dynamics, American Economic Review, 61, 853-72.

Grossman, M. (1972a). The Demand For Health: A Theoretical and Empirical Analysis (NBER, New York).

Grossman, M. (1972b). On the concept of health capital and the demand for health, Journal of Political Economy, 80, 223-55.

Hey, J.D. (1981) Economics in Disequilibrium (Martin Robertson, Oxford).

Menezes, C.F. and D.L. Hanson (1971). On the theory of risk aversion, International Economic Review, 11, 481-87.

Muurinen, J-M. (1982a). Economic research into health and utilization behaviour: a theoretical retrospect and prospect, Mimeo, Department of Economics and Related Studies, University of York.

Muurinen, J-M. (1982b). The demand for health: a generalized Grossman model, Journal of Health Economics, 1, 5-28.

Muurinen, J-M. (1982c). An Economic Model of Health Behaviour - With Empirical Applications to Finnish Health Survey Data (D.Phil dissertation, University of York).

Pauly, M.V. (1980). Doctors and their Workshops: Economic Models of Physician Behaviour (NBER, New York).

Phelps, C.E. (1973). The Demand For Health Insurance: A Theoretical and Empirical Investigation. Monograph R-1054-OED (Rand Corporation, Santa Monica).

Rothschild, M. and J.E. Stiglitz (1970). Incresing risk: I. A definition, Journal of Economic Theory, 2, 225-43.

Van Doorslaer, E.K.A. (1985). Consumer information and the demand for medical care. Paper presented to Sixth International Meeting of the Applied Econometrics Association, December 1985, Rotterdam.

Wagstaff, A. (1986a). The demand for health: a simplified Grossman Model, Bulletin of Economic Research, 38, 93-5.

Wagstaff, A. (1986b). The demand for health: some new empirical evidence, Journal of Health Economics, 5, 195-233.

Zeckhauser, R. and E. Keeler (1970). Another type of risk aversion, Econometrica, 38, 661-65.