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Can we test for Supplier-Induced Demand by comparing informed with uninformed consumers?

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Abstract

Two tests for supplier induced demand are evaluated. Both tests are based on the greater vulnerability to demand inducement of less informed consumers. The first test is whether less informed consumers have higher utilisation of a procedure than more informed consumers. The second is whether they have higher utilisation, given that they have sought medical advice. Both tests are shown to be flawed. The absence of demand inducement is compatible with positive results of either test and the presence of demand inducement is compatible with negative results of both tests.

I am grateful for comments given by Judy Bethwaite, Lew Evans and Neil Quigley.

1. Introduction

How can we tell if physicians *induce* higher demand by recommending excessive treatment? One suggestion is to examine the relationship between the supply of providers (a proxy for motivation to induce demand) and utilisation (e.g. Cromwell and Mitchell, 1986). This approach is problematic because of the lack of identification (Auster and Oaxaca, 1981). Another is to examine the utilisation responses to imposed price cuts, for evidence that suppliers react to a drop in income by inducing more demand (Rice, 1983). This approach may also fail to persuade sceptics because of the identifying assumptions that are required when supply is a determinant of demand. An alternative line of examination is to compare the utilisation of consumers with different levels of information.

It seems plausible that consumers with little information about the implications of symptoms, may be more vulnerable to S.I.D. than well-informed consumers (Dranove, 1988). The idea is that S.I.D. is only possible because of an asymmetry of information between physician and consumer, and the scope for misleading the consumer becomes restricted as the consumer becomes more informed. However this plausibility may be grounded in an assumption that consumers are rational. If consumers make systematic mistakes, then poorly informed consumers might be more or less receptive to their physicians' advice than well informed consumers.

If the plausibility of the suggestion is accepted, it may be expected that consumers with less information would tend to have higher utilisation. If an index of consumer information is available, then this may provide a way to test the S.I.D. hypothesis. Information about symptoms could be proxied with education (e.g.Wilensky and Rossiter, 1983), the results of a survey (e.g. Kenkel (1992)) or by whether the consumer is a health professional (Bunker and Brown (1974), Hay and Leahy (1982), Domenighetti *et al* (1993))[1]. This is the first of two kinds of tests for S.I.D. to be evaluated below.

Kenkel (1992) does not apply this kind of test. He reasons that utilisation may be higher for better informed consumers if poorly informed consumers tend to underestimate the value of medical care. Consequently the first kind of test may indicate misinformation rather than S.I.D. Kenkel looks for underestimation of benefits by poorly informed consumers by checking whether better informed consumers are more likely to seek medical advice. The S.I.D. hypothesis is tested by examining whether poorly informed consumers have higher utilisation than well informed ones, *given that* medical advice has been sought (higher "conditional utilisation"). This is the second type of test to be evaluated below.

In order to evaluate the two tests, it is convenient to have a theoretical basis for claims about what outcomes are compatible with the presence or absence of S.I.D. Evidence for the existence of S.I.D. would presumably be a finding that was inconsistent with, or at least unlikely in, the absence of S.I.D. Conversely evidence

[1] Most studies have not found higher utilisation for the less informed (e.g. Bunker and Brown, Hay and Leahy, van Doorslaer (1987)), although Domenighetti *et al* do.

against S.I.D. might involve findings that would be ruled out by the presence of S.I.D.

Kenkel does motivate his test with reference to the theoretical work of Dranove (1988) who argues that suppliers induce less demand for more informed than less informed consumers. However there are at least two problems with this. The first is that there is an apparent tension between Dranove's "rational-agent" model and Kenkel's suggestion that less-informed consumers systematically underestimate the value of medical care. The second is that it is not clear that the existence of S.I.D. really implies that the less informed consumers will have higher conditional utilisation than the well informed.[2]

In order to evaluate the two tests a theoretical framework will be developed. As a "rational agent" assumption appears to motivate both tests, the models will incorporate this assumption.. The model developed in Section 3 will concern the outcomes that are possible without S.I.D. The model of Section 4 will address outcomes that are possible with S.I.D.

Formal modelling of the effect of improved information requires a characterisation of the quality of information. One approach is to interpret the model of Dardanoni and Wagstaff (1990) in terms of information. In their model the beliefs of consumers about health states are represented by density functions. A mean preserving spread in such a distribution could be interpreted as a decrease in information (p29). If the (unchanged) mean of the distribution is the true underlying health state, then the consumer neither under nor over estimates its seriousness. Dardanoni and Wagstaff argue that this kind of decrease in information will lead to an increase in desired utilisation.

While this conclusion is of interest in its own right, it does not provide an immediate rationalisation for either test. The theoretical effect seems to be in the opposite direction to the (usually) estimated effect. Furthermore the model of Dardanoni and Wagstaff really concerns a different issue. Their theoretical model does not involve symptoms and so the implications are for precautionary demand rather than demand as a response to symptoms.

An alternative characterisation of an increase in information is suggested by Blackwell (1951). He defines one "message service" to be more informative than another if it would be preferred by anyone, irrespective of their utility function. If we interpret symptoms as signals, then we might model more informed consumers as those whose interpretation of symptoms provides a more informative message service. This approach will be developed in Section 2 and applied in Sections 3 and 4.

2. Characterising improvements in information

Assume that the consumer's underlying health state could be bad (H=B) or good (H=G). The consumer is assumed to receive some information or "signal" about his

[2] This is not shown to be an implication of Dranove's model in his 1988 paper, but he has suggested to me that it can be shown to follow if specific distributions are assumed.

or her health state. The consumer then revises his or her prior belief about the probability of the bad health state (π_B). It will be convenient to work with the posterior function $\pi=\pi(r)$ which is the posterior probability of the bad health state when signal r has been received. A signal r is indexed by the proportion of signals that are no more intense than r. Consequently higher values of r correspond to stronger messages. By definition, the probability that $r<r'$ is r', and so r is distributed uniformly on the unit interval. It will be convenient to assume that the posterior function is nondecreasing and continuous from the right. The assumption that $\pi(r)$ is nondecreasing means that more serious symptoms lead to (weakly) higher posterior probabilities of the bad state.

Two further assumptions are made in order to sharpen the focus on informational changes. The first is that it does not alter the underlying incidence of each health state. An informational change is a change in signals and consequently of the posterior function. However the prior probability of the bad state $\pi_B = \int_0^1 \pi(r)dr$ will not be affected.

The second requirement for a purely informational change is that the message r does not directly affect utility. This is not always credible for information about health states. Perhaps the most natural sources of information are symptoms of medical conditions. However symptoms are not purely informational. They can (as pain and discomfort) directly affect utility and consequently the optimal choice of treatment, even when they provide no information about the underlying health state. In the current model, the signal is assumed to be relevant in assessing π but not to appear as an argument of utility. Consequently the conclusions will only be relevant to the informational content of symptoms.

More informed consumers will be better at judging which symptoms are serious and so for a given r, a less informed consumer attributes a different value of the posterior to that attributed a more informed consumer. But this does not mean that the less informed consumer is making a mistake. The interpretation is that the two kinds of consumers differ in their ability to discriminate and rank symptoms by their implications for health states. Both kinds of consumers can have their beliefs confirmed by experience.

Blackwell defines an increase in information, as an informational change that would make a consumer better off, irrespective of the utility function. It is possible to characterise an increase in information as a mean preserving spread of the posteriors. The change must be mean preserving because the mean posterior is the prior. Let utility be $U(x,H)$ where $x \in X$ is the consumer's action and $H \in \{B,G\}$ is his health state. Now overall expected utility is $\max_x\{\pi \cdot U(x,B) + (1-\pi) \cdot U(x,G)\}$, which is convex in π. Consequently, by Ranking Theorem III (e.g. Hirshleifer and Riley 1992, p112), a mean preserving spread in the distribution of π increases expected utility. Therefore such a change would be an increase in information. Furthermore, as only a change to a distribution that is second-order stochastically dominant will increase the expected value for all such convex functions, any such increase in information is a mean preserving spread of posteriors (see appendix).

It will be convenient to interpret an increase in information as a change in the shape of the posterior function. In order to motivate such an interpretation, let $r=\psi(\pi)$ be the inverse[3] function of $\pi(r)$, i.e.

$$Q=\psi(\pi)=\begin{cases} 0 & \textit{if}\ \pi<\pi(0) \\ \sup\{y|\pi(y)\leq\pi\} & \textit{if}\ \pi(0)\leq\pi<\pi(1) \\ 1 & \textit{if}\ \pi(1)\leq\pi \end{cases}$$

This can be substituted into the (uniform) distribution of r, to get $r=\psi(\pi)$, which is the distribution for π. A change in the distribution of π from ψ_1 to ψ_2 is a mean preserving spread *iff* there is no change in the mean (prior)

$$\int_0^1(\pi_1(r)-\pi_2(r))dr=0 \tag{1}$$

and ψ_1 second order stochastically dominates ψ_2.

$$\int_0^y(\psi_1(\pi)-\psi_2(\pi))d\pi\leq 0\ \forall y\in[0,1]. \tag{2}$$

It is demonstrated in the appendix that the latter condition can be rewritten as

$$\int_0^y(\pi_1(r)-\pi_2(r))dr\geq 0\,\forall y\in[0,1]. \tag{3}$$

Therefore an increase in information in this model is a change in the posterior function (from $\pi_1(r)$ to $\pi_2(r)$) where (1) and (3) are satisfied.

3. A model with no S.I.D.

There is a physician (she) and a consumer (he). The consumer preceives a symptom and decides whether to visit the physician. If he does, then the physician offers advice and the consumer then decides whether to accept treatment. Assume that the consumer's utility is separable in consumption and health. Consumption is reduced by copayments when visiting the physician and when receiving treatment. The utility from consumption is v_1 if he does not seek medical advice, v_2 seeks medical advice but does not receive treatment, and v_3 if he seeks medical advice and receives treatment. If he has an untreated medical condition, he has a further disutility of δ. The part-charges are set so that $v_1 > v_2 > v_3 > v_1-\delta$. Therefore the consumer would benefit from receiving treatment only if he has the bad health condition. The doctor has access to perfect information, and she can ascertain the health condition with certainty, so long as the consumer has sought advice. In order to impose the condition that there is no S.I.D., it is assumed that the doctor will truthfully reveal the health state.

[3] The monotonicity assumption on the posterior function places a restriction on the pattern of changes. Without this assumption, some mean preserving spreads would lead to posterior functions with downward sloping sections. Lower values of r could become interpreted as indicating higher chances that the health state is poor. But such changes will not be considered.

Because there are only two health states ($H \in \{B,G\}$) and two treatment levels ($T \in \{0,1\}$), it is straightforward to characterise the expected utility maximising choice of the consumer. If the consumer receives message r, then his expected utility from seeking medical advice is

$$(1-\pi(r)) \cdot v_2 + \pi(r) \cdot v_3$$

as opposed to

$$v_1 - \delta \cdot \pi(r)$$

from not seeking advice. As $\pi(r)$ is nondecreasing in r, the consumer will seek advice if r is high enough and not otherwise. Letting

$$k = \frac{v_1 - v_2}{\delta - v_2 + v_3}$$

and assuming an interior solution, the threshold message is

$$Q = \{r: \lim_{\varepsilon \downarrow 0} \pi(r-\varepsilon) \leq k \ \& \ \pi(r+\varepsilon) \geq k\}.$$

The treatment choice will be

$$T^* = \begin{cases} 0 & \text{if} \quad r < y, \ \forall y \in Q \\ \{0,1\} & \text{if} \quad r \in Q \\ 1 & \text{if} \quad r > y, \ \forall y \in Q \end{cases}$$

This characterisation can be used to examine how informational changes affect utilisation. Assume that there are two types of consumers, those with less information have posterior $\pi_L(.)$ and those with more information have posterior $\pi_H(.)$.

Consider the probability of visiting the doctor. Assuming that Q is a single point, this probability is $1-Q$. As defined in (4), Q depends on the posterior function. If $\pi(r)$ is continuous at Q (i.e. $\pi(Q)=k$), then a higher $\pi(Q)$ implies a lower value of Q and a lower $\pi(Q)$ implies a higher Q.

It is apparent from the characterisation of more information ((1) and (3)), that it is consistent with either a higher or lower value of $\pi(Q)$. A particularly intuitive case is where $\pi_L(r)$ and $\pi_H(r)$ intersect only once. In this case higher information implies a lower posterior for low values of r and a higher one for high values. Visits to the physician would be more likely by the well informed than the less informed ($1-Q_H>1-Q_L$) if visits were sufficiently infrequent by the less informed (i.e. if Q_L was above the intersection).

Now consider the probability that the consumer receives treatment. This is the probability that the consumer has the bad health condition and seeks medical advice,

$$\int_Q^1 \pi(r)dr.$$

This may be expected to be higher for those consumers who are more informed, as $\int_y^1 \pi(r)dr$ will be higher (given (3)) for any y. The intuition is that if both types of consumers seek advice at the same rate, those who are more informed will be more likely to do so when care is really required, and consequently to receive more treatment. However, as noted above, it is possible that the less well-informed consumers may be more likely to seek advice, and this second effect may dominate. Consequently it is possible that less informed consumers have higher expected utilisation. An example in which this is true is

$$k{=}0.5,\quad \pi_L(r)=\begin{cases}1/4 \ \textit{if}\ r<1/2\\ 3/4 \ \textit{if}\ r\geq 1/2\end{cases} \qquad \pi_H(r)=\begin{cases}1/4 \ \textit{if}\ r<2/3\\ 1 \ \textit{if}\ r\geq 2/3\end{cases}$$

In this example, Q_L =1/2 and Q_H=2/3. Expected utilisation is 3/8 for the less informed consumers and 3/9 for those who have better information. Therefore the first kind of test can't prove the existence of S.I.D.

The alternative measure used in the second kind of test is the probability of receiving the procedure given that medical advice is sought. This is

$$\frac{1}{1-Q}\cdot\int_Q^1 \pi(r)dr.$$

As with the unconditional probability, this would be higher for the more informed consumers if Q was the same for both groups, but Q may be higher or lower for the less informed consumers. The overall ranking is again indeterminate. An example where the less informed consumers have a higher conditional expectation of treatment is

$$k{=}7/12,\qquad \pi_L(r)=\begin{cases}1/2 \ \textit{if}\ r<2/3\\ 1 \ \textit{if}\ r\geq 2/3\end{cases} \qquad \pi_H(r)=\begin{cases}1/3 \ \ \textit{if}\ r<1/3\\ 2/3 \ \textit{if}\ 1/3\leq r<2/3\\ 1 \ \ \textit{if}\ r\geq 2/3\end{cases}$$

In this example Q_L^* =2/3 and Q_H^*=1/3. Expected conditional utilisation is 5/6 for the more informed consumers, but 100% for the less informed ones. Therefore the second kind of test can't prove the existence of S.I.D either.

Wilensky and Rossiter suggest that the proportion of visits that are physician rather than consumer initiated be used. The analogue of physician initiated visits would presumably be physician recommended treatment in the current model. The suggestion of Wilensky and Rossiter would then be interpreted as

$$\frac{\int_Q^1 \pi(r)dr}{(1-Q)+\int_Q^1 \pi(r)dr},$$

or equivalently,

$$\frac{\frac{1}{1-Q}\cdot\int_Q^1 \pi(r)dr}{1+\frac{1}{1-Q}\cdot\int_Q^1 \pi(r)dr}.$$

This is higher for less informed consumers *iff* conditional utilisation is higher. Therefore this measure does not have a theoretically determinate ranking for high and low information consumers either.

It appears that neither utilisation, nor utilisation conditional on seeking advice can be used to prove the existence of S.I.D. However, in this model, the absence of S.I.D is not compatible with less informed consumers having *both* higher utilisation and higher conditional utilisation. If consumers with less information have higher utilisation then $Q_L < Q_H$, but if they have higher conditional utilisation then $Q_L > Q_H$. So (at least in this model) if the less informed consumers have both higher utilisation and higher conditional utilisation, then there must (ceteris parabus) be S.I.D.

4. A model with S.I.D.

The model becomes more complicated when the physician is opportunistic in her decision about what advice to offer. In addition to perfect information about the health state, assume that the physician knows the information service of each consumer. To provide a motivation for S.I.D., assume that she has a higher payoff (w_3) when the consumer receives treatment than when he seeks advice but does not receive treatment (w_2). Her objective function is

$$(S-Q)\cdot w_2 + (1-S)\cdot w_3,$$

where 1-Q is the probability that advice is sought and 1-S is the probability that treatment is given. The physician effectively offers the consumer an information service as well as treatment. She gives the consumer a revised estimate π_p of the probability of the bad health state. But the information service may be structured to encourage higher utilisation.

However there are two kinds of constraint on the physician's enthusiasm to recommend treatment. The first kind concerns credibility - the consumer may not believe the advice. The second kind concerns demand - the less informative the advice, the less likely the consumer is to seek that advice. The impact of both of these kinds of constraint depends on the consumer having knowledge of the physician's strategy.

There are a number of possible approaches to the credibility constraint. If consumers are sufficiently naive, there will be no such constraint. Dranove's alternative is that the consumer might not reveal his symptom to the physician, and so has a way to evaluate the advice. The approach taken below is to assume that the physician cannot give a pattern of advice that is inconsistent with the model. this means that in equilibrium the information service must be coherent and more informative than the consumer's original posterior on $[Q,1]$.

Now consider the demand constraints. The two components of demand are the propensity to seek medical advice and the propensity to accept treatment. Given that advice has been sought and is "credible", the consumer will consent to treatment when

$$\pi_p \geq \frac{v_2 - v_3}{\delta}.$$

The utilisation rate will be determined by probability that this condition is satisfied, and by Q. The consumer's decision to seek advice is made with knowledge of the physician strategy. Therefore the rate at which the consumer seeks medical advice is determined by the probability that the consumer expects higher utility from seeking advice than from not seeking advice.

The constraints on the physician's maximisation are formalised in the appendix. In general the problem is fairly intractable, but there are classes of examples to which solutions are straightforward. One such class is described in the appendix. It contains $\pi_L(r)$ in the following example.

$$\delta=1,\ v_1-v_2=0.5,\ v_2-v_3=0.8$$

$$\pi_H(r)=\begin{cases}0 & \text{if } r<1/2\\ 1 & \text{if } r\geq 1/2\end{cases} \qquad \pi_L(r)=\begin{cases}0.4 & \text{if } r<1/2\\ 0.6 & \text{if } r\geq 1/2\end{cases}$$

In this example, $\pi_H(r)$ represents full information and so the physician can not manipulate utilisation by offering increased information. The fully informed consumer will visit the physician and accept treatment when and only when his health condition is bad. Therefore $Q_H=S_H=1/2$. The utilisation rate is 1- S_H=50% and the rate conditional on a visit is 100%.

As shown in the appendix, the less informed consumer has an expected utilisation of 1- S_L=5/16 and expected utilisation conditional on a visit of 5/8. Both utilisation and conditional utilisation have lower expected values for the less informed consumer than for the well informed one. Therefore the existence of S.I.D. is compatible with well informed consumers having both higher utilisation and higher conditional utilisation.

The intuition is that, as when there is no S.I.D., the well informed consumer is better at judging when he needs medical advice. In this example, both groups visit the physician at the same rate. So the well informed consumer is more likely to have the bad health state given that he visits the physician. Even though the well-informed consumer receives less *unnecessary* treatment, he may receive more treatment overall (and more treatment conditional on a visit) than the less informed consumer.

Unfortunately neither higher utilisation for more informed consumers, nor higher utilisation conditional on visits, provide an immediate way to disprove the existence of S.I.D.

5. Conclusions

Neither of two proposed tests for the existence of S.I.D. are found to be valid. Higher utilisation of a procedure for less informed consumers cannot be considered a testable implication of S.I.D. as it may be false with S.I.D. and may be true without S.I.D. Higher utilisation of a procedure, given that medical advice has been sought, faces the same problem.

Just because a result is possible in a theoretical model does not mean that it is possible, let alone likely, in the real world. Any test will rely on supporting assumptions, and they may not be consistent with the assumptions of the models presented above. This may be particularly important for the model of S.I.D in

Section 4. For example, it is assumed that that all agents are perfect Bayesian decision makers in a well-understood environment, but physicians filter information in order to increase their incomes. This is somewhat at odds with the following suggestion by Hay and Leahy (p232).

> "More likely, there is a 'grey area' of acceptable treatment patterns. Aggressive physicians will promote supranormal utilization patterns and conservative physicians will proceed cautiously."

The theoretical models are, as they must be, unrealistic. Nevertheless they do illuminate some fairly intuitive reasons to doubt the validity of the two suggested tests. For example -

(i) More informed consumers may seek medical advice more often than less informed consumers. One example (articulated for the case where the posteriors of the two groups cross only once) is when medical advice is sought "too infrequently" and increased information would lead to lower demand.

(ii) For a given rate of seeking medical advice, well informed consumers may seek advice more when treatment is actually necessary than less informed consumers.

(iii) Whether or not the physician is recommending more unnecessary treatment to the less informed consumers, she may be recommending more necessary treatment and more treatment in total to the more informed consumers.

To the extent that these mechanisms are plausible, the burden of proof is on those who wish to use the suggested tests for S.I.D.

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Appendix

(i) An increase in information is a mean preserving spread of posteriors.

If there is an increase in information, then there will be an increase in expected utility, with any utility function. If v(0,B)=v(0,G)=0 and v(1,G)-v(1,B)=-1, then expected utility is
$\max\{(1-\pi)\cdot v(0,B)+\pi\cdot v(0,G),\ (1-\pi)\cdot v(1,B)+\pi\cdot v(1,G)\}=\max\{0, v(1,B)-\pi\}$. Now continue as suggested in Hirshleifer and Riley (p114).

(ii) Derivation of Condition (3)

Condition (2) can be rewritten as

$$\max_{y\in[0,1]}\{\int_0^y(\psi_1(\pi)-\psi_2(\pi))d\pi\}\leq 0,$$

which can be checked by looking at the boundary points and any points where ψ_1 crosses ψ_2. from above. At y=0, $\int_0^0\psi_1(\pi)d\pi=\int_0^0\psi_2(\pi)=0.$ At y=1, $\int_0^1\psi_1(\pi)d\pi=\int_0^1\psi_2(\pi)=1-\pi_B$. Therefore if the maximum is strictly positive, it must be at a point where ψ_1 crosses ψ_2 from above. This could be where $\psi_1(\pi)=\psi_2(\pi)$ (i.e. at points satisfying the F.O.C.) or where ψ_1 jumps over ψ_2 Both kinds of points are contained in the set $\tilde{\Pi}=\{y|\lim\varepsilon\downarrow 0\ \psi_1(y+\varepsilon)\geq\psi_2(y+\varepsilon)\ \&\psi_1(y-\varepsilon)\leq\psi_2(y-\varepsilon)\}$.

Condition (2) becomes $\int_0^y(\psi_1(\pi)-\psi_2(\pi))d\pi\leq 0\ \forall y\in\tilde{\Pi}$. The crossover points can also be described in terms of the posterior functions
$\tilde{Q}=\{y|\lim\varepsilon\downarrow 0\pi_1(y+\varepsilon)\leq\pi_2(y+\varepsilon)\&\pi_1(y-\varepsilon)\geq\pi_2(y-\varepsilon)\}$.
But as the area between two curves, up to a crossover, can be found by integrating either the original or the inverse functions, condition (2) is equivalent to

$$\int_0^y(\pi_1(B|Q)-\pi_2(B|Q))dQ\geq 0\forall y\in\tilde{Q},$$

and as $\tilde{Q}$ contains all possible minima of this function in [0,1],

$$\int_0^y(\pi_1(B|Q)-\pi_2(B|Q))dQ\geq 0\forall y\in[0,1],$$

which is condition (3). A similar argument is used to show that (3) entails (2).

(iii) Supplier-Induced demand

The physician knows the consumer's posterior, the consumer's assessment of the symptoms and the underlying health state. If the consumer seeks her advice, she reports a value of π_p. She maximises

$$(S-Q)\cdot w_2 + (1-S)\cdot w_3,$$

subject to the demand and credibility constraints, by choosing a mapping,

$$g: \Pi \times [0,1] \times \{B, G\} \to [0,1],$$

where Π is the space of posterior functions.

For a given posterior function, the strategy can be described as a function giving the density of values of π_p given a value of r and a value of H, or equivalently and more conveniently of just a value of r, $f(t|r)$.

The credibility constraints are analogues of the characterisation of an increase in information, (1) and (3), on $[Q,1]$.

$$\int_Q^1 \pi(r_1)dr_1 = \int_0^1 t \cdot \int_Q^1 \{f(t|r)dr\}dt$$

(1')

$$\int_Q^y \pi(r_1)dr_1 \geq \int_0^D t \cdot \int_Q^1 \{f(t|r)dr\}dt \quad \forall y, \forall D\, s.t. \int_0^D \int_Q^1 \{f(t|r)dr\}dt = y - Q \tag{3'}$$

The first demand constraint is that expected utilisation will be the probability that treatment will be accepted,

$$1 - S = \int_Q^1 \{\int_\gamma^1 f(t|r)dt\}dr, \tag{4}$$

where $\gamma = \dfrac{v_2 - v_3}{\delta}$.

The second demand constraint is that medical advice will only be sought when it leads to higher expected utility for the consumer. Therefore

$$1 - Q = \int_0^1 \mathrm{I}(U_1(r) - U_2(r))dr, \tag{5}$$

where

$$U_1(r) = v_2 \cdot \int_0^\gamma f(t|r)dt + v_3 \cdot \int_\gamma^1 f(t|r)dt - \delta \cdot \int_0^\gamma t \cdot f(t|r)dt,$$

is the expected utility (given r) of seeking medical advice,

$$U_0(r) = v_1 - \delta \cdot \pi(r),$$

is the expected utility (given r) of not seeking medical advice, and I(x) is an indicator function taking one when x is nonnegative and zero otherwise.

Note that if $\pi_p < \gamma$, then $\pi_p = 0$. Otherwise it would be possible to increase both the probability that $\pi_p = 0$ and the probability that $\pi_p \geq \gamma$, in consistency with (1') and (3'), and easing (4) and (5). But this means that (5) simplifies because

$$\delta \cdot \int_0^\gamma t \cdot f(t|r)dt = 0.$$

The problem is still fairly intractable in general, but it is possible to work with a class of simple examples. In this class, consumers can only discriminate two classes of symptom (say "sick" and "well"). The posterior functions take the form

$$\pi(r)=\begin{cases}\alpha_1 \text{ } if \text{ } r<1/2\\ \alpha_2 \text{ } if \text{ } r\geq 1/2\end{cases}.$$

Assume that

$$\frac{v_2-v_3}{\delta}>\alpha_2>\frac{v_1-v_2}{\delta}>\alpha_1. \tag{6}$$

Now Q≥1/2. Otherwise $\pi(Q)=\alpha_1$, so (5) implies that v_1-Ev|v∈$\{v_2,v_3\}=\delta\cdot\alpha_1$. But as $v_2>v_3$, this violates (6). But then any $r\geq Q$ is .indistinguishable and so (5) implies that

$$v_1-\delta\cdot\alpha_2\leq v_2\cdot\frac{S-Q}{1-Q}+v_3\cdot\frac{1-S}{1-Q} \tag{7}$$

Letting $\lambda=\frac{1-S}{1-Q}$, the objective function can be rewritten as $(1-Q)\cdot((1-\lambda)\cdot w_2+\lambda\cdot w_3)$. It is apparent that for any given value of Q, the physician would like λ to be as high as possible. But λ is bounded from above by (7),

$$\lambda\leq\max\left(\frac{1-\frac{v_1-v_2}{\delta}}{\frac{v_2-v_3}{\delta}},1\right). \tag{8}$$

Given λ, the physician prefers the lowest value of Q possible. Therefore she can do no better than Q=1/2, and λ determined by (8) holding with equality. But this is attainable. The optimal function $f(t|r)$ is not unique, but one which can implement these values of Q and λ without violating any constraints is

$$\Pr(t|r)=\begin{cases}0 & if \text{ } t\notin\{0,\pi_0\}\\ \frac{S-Q}{1-Q} & if \text{ } t=0\\ \frac{1-S}{1-Q} & if \text{ } t=\pi_0\end{cases}$$

where $\pi_0=\lambda\cdot\alpha_2$.

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