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WORKSHOP IN HEALTH ADMINISTRATION STUDIES

AUTUMN, 1988

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"Insurance, Information, and the Pattern of Aggregate Technical
Change in Medical Care"

WORKSHOP PAPER

for

Thursday, November 3, 1988

Rosenwald 405

3:30 to 5:00 p.m.

INSURANCE, INFORMATION, AND THE PATTERN OF AGGREGATE TECHNICAL CHANGE
IN MEDICAL CARE

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Preliminary Draft
July 1988
Current Version
October 1988
Comments are appreciated.

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Abstract

The effect of a technical advance on consumer welfare depends on the type of technical change and the form of insurance contract. A simple three-parameter description of medical technology is introduced to investigate the relationships between technical change, welfare, health, and type of insurance contract. Conventional coinsurance contracts may have consumer welfare decrease in technical advances that increase the potential to treat severe illness, while Health Maintenance Organizations may have welfare decrease in advances that reduce the indirect costs of treatment. Even in full information contracts, technical changes that increase consumer welfare may reduce the health of some patients.

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I. Introduction

The relationships between technical change in medical care, consumer welfare, and patients' health depend critically on the definition of technical progress, the criterion for adoption of a new technology, and the prevailing form of insurance contract. Feasible insurance arrangements, in turn, depend on the types of information that are mutually observed by the parties to the insurance contract. This paper introduces a simple three parameter description of aggregate medical care technology and a formalization of illness that distinguishes between diagnosis and severity. These new ingredients open the way for the analysis of several key issues relating to the development of new technology and the insurance arrangements of consumers.

Examples of the questions that will be analyzed are the following. Can some types of technical advance actually reduce consumer welfare? If so, then what types of technical advances are the culprits? How do the answers depend on the form of insurance contract? That is, do the effects of technical progress depend on whether consumers have conventional cost-based insurance or, instead, share risk through so-called prepaid health plans such as health

maintenance organizations (HMOs)? How do the criteria that determine whether or not a new technology is adopted by the medical care industry affect the types of technical advance, the changes in welfare, and the changes in health that occur over time? Again, how does the form of insurance contract matter?

Models of two prevalent types of asymmetric information insurance contracts will be considered. The source of the asymmetry is that the insurer cannot observe the exact illness and severity of a patient. Conventional insurance (CI) arrangements, in which the patient pays a fraction of incurred medical expenses, are one type of contract to be analyzed. Such cost-based insurance contracts are sometimes applauded for their relative lack of intrusion of the insurer into medical decision making but are criticized as leading to large amounts of treatment and excessive medical bills.

The other type of insurance arrangement to be analyzed is the prepaid health plan, or HMO. In exchange for a premium, the HMO covers the medical bills of the insured. Excessive use of resources is controlled by imperfect monitoring of doctors by management. Penalties of various forms are imposed on doctors who overtreat. HMOs are commonly promoted as an insurance agreement that controls costs more effectively than CI at the expense of interference by management in medical decision making. Another criticism of both HMOs and Medicare's prospective payment system (PPS) - by which hospitals are reimbursed a particular amount conditional on diagnosis - is that patients with relatively severe forms of their particular illness will not be adequately treated. Implicit in this criticism is the assumption that doctors and hospitals are unwilling to absorb any risk. That is, they will not give extra treatment to a relatively severe case with the hope of making up for this with relatively small treatment on a relatively mild case. In the formal analysis to follow, I will model a worst case scenario HMO that sets a maximum

amount of allowed treatment conditional on diagnosis. Since the formalization of the illness process introduced in this paper distinguishes diagnosis from severity, the model captures this common complaint made by HMO and PPS detractors.

An analysis of technology under a full information insurance contract will also be considered. Not only does this serve as a baseline, first-best case, but the full information contract also describes an ideally operating prepaid health plan in which the doctor or hospital optimally responds to variations in severity that cannot be observed by management.

The results show that the way that a particular insurance contract is tailored to deal with informational asymmetries is closely related to the type of technical advance that can have perverse effects on consumer welfare. A technical advance that increases the ability to treat more severe illnesses can decrease competitive equilibrium consumer (ex ante) welfare under a conventional coinsurance system since severely ill patients only pay a fraction of the cost of this increased treatment. Such an advance cannot decrease welfare under an HMO scheme. An HMO can effectively stop the increased care with the upper limits it sets on treatment levels. On the other hand, a technical advance that reduces the indirect costs of treatment to patients (such as travel time, treatment time, or undesirable side effects from medical treatment) can reduce the competitive equilibrium welfare of HMO consumers. Indirect costs are the only costs paid by patients (ex post), and a reduction in these costs increases inefficient overuse in the HMO. A coinsurance regime allows the coinsurance rate to adjust in response to the technical advance so that reductions in indirect costs always improve welfare under CI.

A technical advance that reduces the marginal indirect cost of treatment

by a dollar is a perfect substitute for an advance that reduces the direct (pecuniary) marginal cost of treatment by a dollar. This result holds under both full information and equilibrium CI contracts. Even though a CI contract pays a particular fraction of only the direct (pecuniary) medical costs, it turns out that the competitive equilibrium coinsurance rate adjusts to technical advances in such a way that the two types of technical progress are perfect substitutes in their effects on equilibrium consumer welfare, premiums, and average health. The perfect substitute result does not hold for the HMO contract.

Two different criteria for adoption of a new technology are considered. If a new technology is only adopted if adoption will lead to an equilibrium increase in ex post health for some illness states and no decrease in health for any states, then the full information regime will necessarily see consumer welfare increasing as new technologies are adopted. This result does not hold under either of the asymmetric information contracts. If a new technology is only adopted if it will increase equilibrium consumer welfare, then, under all types of contracts considered, it is possible for new technologies to be adopted that reduce the ex post health of some patients. This potential for conflict between the ex ante interests of the pool of insured consumers and the ex post interests of some patients exists even in a full information world. However, it will be seen that the conflict disappears from a full information world if a potential new technology can be sufficiently unbundled.

The result that technical advances can reduce consumer welfare in equilibrium coinsurance contracts was first shown by Goddeeris (1984). The three parameter description of technology that is introduced in the present paper allows a stricter characterization of the type of technical progress that gives this perverse result. The utility decreasing effects of some types

of technical progress hinge on the inefficient overuse of medical care first noted by Pauly (1968). Zeckhauser (1970) studies various forms of medical insurance arrangements including cases with the same sorts of informational asymmetries as those studied here. The inefficient use of medical treatment is another example of the tradeoff between risk sharing and efficiency in principal-agent relationships studied by a number of authors including Spence and Zeckhauser (1971), Harris and Raviv (1978), Holmstrom (1979), and Shavell (1979). In this paper the insurer is a risk neutral principal while the patient/doctor is the risk averse agent. I will assume throughout that the doctor is a perfect agent acting in behalf of the patient and will sometimes use "doctor" and "patient" synonymously.

Besides Goddeeris (1984), other papers examining the relationship between insurance and technology are Feldstein (1977) and Pauly (1980). These papers aim at different issues from those considered here. Also, those models treat hospitals as an explicit economic actor with preferences that depend on hospital output and quality. Quality represents the level of technology and is treated as a homogeneous or composite product. My model emphasizes different types of technology, and medical providers such as hospitals or doctors take a background role - they merely act in the interest of their insured patients.¹ The two key players in my model are the insurers and the insureds.

The paper is organized as follows. Section II introduces basic ingredients and terminology to be used throughout. The full information case appears in Section III with the following two sections devoted to asymmetric information cases. Section IV considers conventional coinsurance (CI), and Section V considers the prepaid health plan (HMO). Section VI concludes.

II. Basic Ingredients

This section introduces some basic ingredients and terminology used throughout the paper.

Illness and Treatment Process

There are N possible illnesses indexed by $i = 1, \dots, N$. The probability of occurrence of illness i is p_i , while $p_0 = 1 - \sum_i p_i$ is the probability of no illness. Each illness can vary in severity with the realization of severity given by ϵ_i . All severity levels (ϵ_i) are non-negative with conditional distribution $F_i(\epsilon_i)$. Thus, $\int_0^{\infty} dF_i(\epsilon_i) = 1$.²

Let H denote the level of health. An individual with no illness has $H = \hat{H}$. An illness shock of ϵ_i reduces H to $\hat{H} - \epsilon_i$. Medical treatment works against the illness shock toward restoration of health. Treatment level m results in post-treatment health equal to $\hat{H} - \epsilon_i + m$ with the restriction that m is less than or equal to ϵ_i - this restriction says that medical treatment cannot raise health above its no illness level.

Aggregate Medical Technology

The aggregate medical technology (T) is described by the 3-tuple $T = (n, a, B)$, where n refers to the constant marginal (and average) indirect (or non-pecuniary) cost per unit of treatment, a refers to the constant marginal (and average) direct (or pecuniary) cost per unit of treatment, and B refers to the technical boundary of treatment. Medical treatment m cannot

exceed B - the technical boundary (B) captures the extent to which healing is technically feasible.

A new discovery or invention that increases the value of B makes it possible to treat more severe illnesses (those with $\epsilon_i > B$) to a greater extent than was formerly possible. Indirect marginal cost (n) refers to those costs of treatment incurred by the patient which do not represent the direct use of medical services or products. Examples of these indirect costs are the cost of the patient's time in receiving treatment and the disutility caused by side effects of treatment. Development of surgical techniques which are less intrusive or pharmaceuticals with milder adverse reactions will reduce n . Direct marginal costs (a) refer to those costs of treatment directly related to the consumption of medical goods and services such as the doctor's bill and costs of laboratory and other services. Reductions in the wages of medical personnel (quality held constant) or development of cheaper lab tests or techniques requiring less manpower to provide the same treatment are innovations that reduce a .

The term "technical change" refers to a change in T . The term "technical advance" will be used in accord with the common intuition as to what constitutes an advance. That is, a technical advance in n or a refers to a decrease in n or a , while a technical advance in B refers to an increase in B .

Preferences

Risk averse consumers desire to maximize standard expected utility with elementary utility functions of the form $U(y - r + G(H) - c(m))$ with $U' > 0$ and $U'' < 0$. The argument of $U(\cdot)$ is income (y) minus insurance premium (r) plus the monetary value of ex post health ($G(H)$) minus the net costs to the

consumer $c(m)$ of consuming medical treatment level m . The function $G(H)$ is assumed to have $G' > 0$ and $G'' < 0$. The possible states of the world are the no illness state and all possible realizations of ϵ_i for all i .

Other Terminology

The model is set up such that consumers enter into insurance contracts to maximize expected utility. Subsequently, a consumer may receive an illness shock and then will act to maximize ex post utility subject to the rules of the insurance contract. I will use the term "consumer" to refer to the ex ante agent, while the term "patient" will be reserved for those who receive ex post illness shocks. The term "consumer welfare" refers to the maximized value of expected utility.

Two different criteria for the adoption of a new T will be considered. The consumer welfare criterion states that a newly available technology (T') will be adopted and replace the former technology (T^0) iff consumer welfare is greater under T' than T^0 . The other adoption criterion for a new technology is called the Pareto health improving (PHI) criterion. Under PHI a new alternative T' will be adopted to replace T^0 iff this will result in an equilibrium increase in the health of some types of patients with no decrease in the health of any types of patient.

III. Full Information

This section analyzes a full information world in which the insurer can fully verify the illness realization (ϵ_i) of a policy holder. In competitive equilibrium, insurers will offer contracts that maximize consumer expected

utility and leave zero expected economic profit to the risk neutral insurance companies. Formally, the equilibrium contract solves

$$\begin{aligned} & \max_{\{m(\epsilon_i)\}, \{L(\epsilon_i)\}} p_0 U(y - r + G(\hat{H})) \\ & + \sum_i \left\{ p_i \left[\int \{U(y - r + G(\hat{H} - \epsilon_i + m(\epsilon_i)) - Cm(\epsilon_i) + L(\epsilon_i))\} dF_i(\epsilon_i) \right] \right\} \end{aligned} \quad (1)$$

$$\text{subject to } r - \sum_i \left\{ p_i \int L(\epsilon_i) dF_i(\epsilon_i) \right\} = 0$$

$$\text{and } 0 \leq m(\epsilon_i) \leq B \text{ for all } \epsilon_i,$$

where $C = n + a$ is the marginal cost of treatment which includes the indirect and direct costs, and $L(\epsilon_i)$ is the payment from insurer to patient if event ϵ_i occurs. The second inequality constraint in (1) is the limit on treatment due to the technical boundary.

The first-order conditions for interior solutions with $m(\epsilon_i) > 0$ are

$$G'(\hat{H} - \epsilon_i + m(\epsilon_i)) - C - \lambda(\epsilon_i) = 0, \quad \lambda(\epsilon_i) \geq 0, \quad \lambda(\epsilon_i)[B - m(\epsilon_i)] = 0, \quad (2)$$

and

$$U'(y - r + G(\hat{H} - \epsilon_i + m(\epsilon_i)) - Cm(\epsilon_i) + L(\epsilon_i)) - E\{MU\}_F = 0, \quad (3)$$

for each ϵ_i , where $E\{MU\}_F$ is the expected value of marginal utility in the full information contract and $\lambda(\epsilon_i)$ is a Kuhn-Tucker multiplier associated with the technical boundary. Condition (2) states that medical treatment is

consumed such that the marginal benefit equals full marginal cost and shows the first-best efficiency of a full information contract. Condition (3) is the standard full information result that marginal utility is equalized across states. From the strict concavity of $U(\cdot)$ it follows that the argument of $U(\cdot)$ is equalized across states, and insurance payments are

$$L(\epsilon_i) = Cm(\epsilon_i) + G(\hat{H}) - G(\hat{H} - \epsilon_i + m(\epsilon_i)). \quad (4)$$

Equation (4) shows that *all* treatment costs are paid by the insurer, and the final two terms represent compensation for a less than complete recovery.

The full information contract has the appearance of the ideally functioning HMO. All treatment costs are paid by the insurer and treatment is conditioned on illness according to (2). Even this first best contract will exhibit an ex post conflict between patients (or their perfect agent doctors) and the insurer. Given that all expenses are covered, the patient would like to consume more medical care than that implied by (2). The common complaint that HMOs restrict doctors' treatment choices is not at all inconsistent with HMOs' representing a first-best insurance arrangement.

The medical treatment consumed conditional on ϵ_i is derived from (2) after taking into account possible corner solutions:

$$m(\epsilon_i) = \begin{cases} 0 & \text{if } \epsilon_i \in I_F \\ \epsilon_i + G^{-1}(C) - \hat{H} & \text{if } \epsilon_i \in II_F \\ B & \text{if } \epsilon_i \in III_F, \end{cases} \quad (5)$$

where the state space of ϵ_i has been broken into three subsets defined as

follows: $I_F = \{\epsilon_i | 0 \leq \epsilon_i \leq \hat{H} - G^{-1}(C)\}$,

$II_F = \{\epsilon_i | \hat{H} - G^{-1}(C) \leq \epsilon_i \leq \hat{H} - G^{-1}(C) + B\}$, and

$III_F = \{\epsilon_i | \hat{H} - G^{-1}(C) + B \leq \epsilon_i\}$. Subset I_F represents illnesses that are so mild that no treatment is consumed;³ subset II_F represents severities such that an interior solution to (2) obtains and the technical boundary B does not restrict treatment; and subset III_F represents illness shocks that are so severe that B forms a binding constraint on treatment.

Equilibrium consumer welfare under full information (V_F^*) is inversely related to the equilibrium premium (r_F^*). Since condition (3) implies that the argument of $U(\cdot)$ is equalized across states and the sum of the probability weights across states adds to one,

$$V_F^* = U(y - r_F^* + G(\hat{H})) . \quad (6)$$

Since $U' > 0$, it follows that $dV_F^*/dr_F^* < 0$.

The zero expected profit condition for insurers and equations (4) and (5) give

$$\begin{aligned} r_F^* = & \sum_i \left\{ p_i \left[\int_{I_F} \{G(\hat{H}) - G(\hat{H} - \epsilon_i)\} dF_i(\epsilon_i) \right. \right. \\ & + \int_{II_F} \{Cm(\epsilon_i) + G(\hat{H}) - G(G^{-1}(C))\} dF_i(\epsilon_i) \\ & \left. \left. + \int_{III_F} \{CB + G(\hat{H}) - G(\hat{H} - \epsilon_i + B)\} dF_i(\epsilon_i) \right] \right\} , \end{aligned} \quad (7)$$

where $m(\epsilon_i)$ in the second integral is given by the second line of (5).

Technical advances of all three varieties have the expected effects on consumer welfare and on average health. The partial effects of the elements

of T on consumer welfare are derived from (6) and (7):

$$\begin{aligned}
 -(\partial V_F^*/\partial n) = -(\partial V_F^*/\partial a) = -(\partial V_F^*/\partial C) = U'(\cdot) \sum_i \left\{ p_i \left[\int_{II_F} m(\epsilon_i) dF_i(\epsilon_i) \right. \right. \\
 \left. \left. + B \int_{III_F} dF_i(\epsilon_i) \right] \right\} > 0 ,
 \end{aligned} \tag{8}$$

$$\partial V_F^*/\partial B = U'(\cdot) \sum_i \left\{ p_i \left[\int_{III_F} (G'(\cdot) - C) dF_i(\epsilon_i) \right] \right\} \geq 0 . \tag{9}$$

The strict inequality in (9) holds as long as the technical boundary constraint is strictly binding for a non-zero measure of illness states as this activates the Kuhn-Tucker multiplier in (2). Inequality (8) shows not only that advances which reduce indirect and direct treatment costs induce an increase in consumer welfare but also that advances in n and a are perfect substitutes. Even though am is the cost component attributed to medical care in national income accounts, a dollar reduction in indirect costs of treatment contributes as much to welfare as a dollar reduction in a .

Average ex post health under full information (\bar{H}_F) implied by (5) is

$$\begin{aligned}
 \bar{H}_F = p_0 \hat{H} + \sum_i \left\{ p_i \left[\int_{I_F} (\hat{H} - \epsilon_i) dF_i(\epsilon_i) + \int_{II_F} G^{-1}(C) dF_i(\epsilon_i) \right. \right. \\
 \left. \left. + \int_{III_F} (\hat{H} - \epsilon_i + B) dF_i(\epsilon_i) \right] \right\} .
 \end{aligned} \tag{10}$$

Differentiation of (10) establishes that \bar{H}_F increases in technical advances that reduce either n or a (in fact, they are perfect substitutes) or advances

that increase B .

Now let us consider the different criteria for replacement of an old technology with a new one. It is possible for the consumer welfare adoption criterion to lead to changes in T that are not Pareto health improving. Consider a case in which current technology $T^0 = (n^0, a^0, B^0)$ is inferior in consumer welfare to a new technology $T' = (n^0, a^0 + da, B^0 + dB)$. The new technology entails an increase in the treatment frontier of dB and a small increase in direct marginal cost of da so that V^* rises.⁴ Perhaps this represents a new innovation in radiologic imaging that increases treatment potential for some ϵ_i but also increases the cost of some cases that were just as treatable under T^0 . Since $V^*(T') > V^*(T^0)$, (6) and (7) imply that da is small enough so that

$$\sum_i \left\{ p_i \left[\int_{III_F} (G'(\cdot) - C) dF_i(\epsilon_i) \right] \right\} dB \tag{11}$$

$$> \sum_i \left\{ p_i \left[\int_{II_F} m(\epsilon_i) dF_i(\epsilon_i) + B \int_{III_F} dF_i(\epsilon_i) \right] \right\} da .$$

Differentiation of the second integrand in (10) with respect to a shows that the change in health of patients with $\epsilon_i \in II_F$ is $(G'')^{-1} < 0$. Thus, some patients are worse off even though $V^*(T') > V^*(T^0)$.

The consumer welfare criterion would always be consistent with PHI if a new technology could be unbundled into its component pieces. In the previous example, we would keep dB and throw out da . But how realistic is this? Many technical changes in medical practice involve fixed costs whether in the form of indivisible machinery or embodied human capital — a doctor learns a new technique and this replaces an old one. Young doctors never learn some things that their predecessors learned, some of which may still be useful. The

bundled situation appears to be more relevant.

The PHI criterion for new technology adoption results in increased health and increased consumer welfare with each newly adopted technology. That \bar{H} rises is a trivial consequence of the definition of PHI. To see why V^* necessarily rises, notice that a technical change that meets the PHI criterion must be one of only three types: (i) C falls with B constant, (ii) B rises with C constant, or (iii) C falls and B rises. From (8) and (9), it follows that V^* must rise.

IV. Conventional Coinsurance

This section will consider an asymmetric information world with conventional coinsurance (CI) contracts. The insurer cannot observe ϵ_i but can observe consumption of medical treatment (m). The patient and doctor observe ϵ_i and decide upon m . The insurance contract sets some fraction (θ) of the direct treatment costs that will be paid by the insurer. The patient pays the remaining fraction ($1 - \theta$) of the direct medical bill and also must absorb all of the indirect costs. The fraction $1 - \theta$ is often called the coinsurance rate. This conventional type of contract is a form of cost-based reimbursement since the reimbursement from insurer to insured (θam) is based on the direct costs of treatment (am).

To determine demand for medical treatment as a function of ϵ_i , n , a , B , and θ , we must solve the patient's post-illness shock optimization problem:

$$\max_m U(y - r + G(\hat{H} - \epsilon_i + m) - C_\theta m) \quad (12)$$

subject to $0 \leq m \leq B$,

where $C_\theta = n + (1 - \theta)a$ is the sum of the indirect and coinsured direct marginal costs faced by the insured patient. The first-order condition on an interior with $m > 0$ is

$$G'(\hat{H} - \epsilon_i + m(\epsilon_i)) - C_\theta - \lambda(\epsilon_i) = 0, \lambda(\epsilon_i) \geq 0, \lambda(\epsilon_i)[B - m(\epsilon_i)] = 0. \quad (13)$$

The Kuhn-Tucker multiplier $\lambda(\epsilon_i)$ equals zero when the technical boundary constraint is not strictly binding. A comparison of (13) with (2) shows that more medical treatment is consumed in the CI contract than in the full information contract since $C_\theta < C$. This is the standard overuse result pointed out by Pauly (1968) and the standard loss of efficiency result in principal-agent models with risk sharing and asymmetric information. Only sufficiently severe illnesses such as ϵ_i^* in figure 1 generate an efficient choice of m , and this is only because the limits of technology have been reached.

Unlike the full information case there is no ex post conflict between the patient/doctor and the insurer. Given that the insurer has agreed to pay θ times the direct treatment costs, the patient is free to choose as much m as desired. The state space of ϵ_i can be partitioned in a similar fashion to the previous derivation of (5) to give the demand for medical treatment as

$$m(\epsilon_i) = \begin{cases} 0 & \text{if } \epsilon_i \in I_C \\ \epsilon_i + G'^{-1}(C_\theta) - \hat{H} & \text{if } \epsilon_i \in II_C \\ B & \text{if } \epsilon_i \in III_C, \end{cases} \quad (14)$$

where $I_C = \{\epsilon_i | 0 \leq \epsilon_i \leq \hat{H} - G'^{-1}(C_\theta)\}$,

$$\text{II}_C = \{\epsilon_i | \hat{H} - G^{-1}(C_\theta) \leq \epsilon_i \leq \hat{H} - G^{-1}(C_\theta) + B,$$

$$\text{and III}_C = \{\epsilon_i | \hat{H} - G^{-1}(C_\theta) + B \leq \epsilon_i\}.$$
⁵

The competitive equilibrium CI contract will be that contract that maximizes expected utility for consumers subject to zero expected profits for insurers and the ex post behavior of patients given by (14). Formally,

$$\max_{\theta} p_0 U(y - r + G(\hat{H}))$$
(15)

$$+ \sum_i \left\{ p_i \left[\int (U(y - r + G(\hat{H} - \epsilon_i + m(\epsilon_i))) - C_\theta m(\epsilon_i)) dF_i(\epsilon_i) \right] \right\}$$

$$\text{subject to } r - \theta a E(m) = 0,$$

where $m(\epsilon_i)$ is given by (14), and $E(m)$ is the expected value of m across all states including no illness.⁶ The first-order condition for (15) is

$$-E(MU)_C E\left(m + \theta \frac{\partial m}{\partial \theta}\right)$$
(16)

$$+ \sum_i \left\{ p_i \left[\int_{\text{II}_C} (U'(\cdot) m(\epsilon_i)) dF_i(\epsilon_i) + B \int_{\text{III}_C} (U'(\cdot)) dF_i(\epsilon_i) \right] \right\} = 0,$$

where $E(MU)_C$ is the expected value of marginal utility in the equilibrium coinsurance contract, the $E(\cdot)$ operator refers to the expectation across all states, and $m(\epsilon_i)$ is given by (14). Assume that the second-order condition holds.

Condition (16) can be rewritten as

$$-E(MU)_C E\{m \cdot \eta_{m, \theta}\} + \text{Cov}(MU, m) = 0,$$
(17)

where $\eta_{m,\theta}$ is the elasticity of demand for medical care with respect to the insured fraction (θ) and is necessarily positive. This implies that the covariance between $U'(\cdot)$ and m (written as $Cov(MU, m)$) is necessarily positive.⁷ From $U'' < 0$ and (14) it follows that patients with greater ϵ_i are ex post worse off than patients with lower realizations of ϵ_i . Risk sharing is traded off against overuse of treatment in this asymmetric information case.

Technical advances in n and a have the expected effects on consumer welfare (V_C^*). Technical advances in B may actually reduce equilibrium welfare. First, let us look at advances that affect the indirect and direct marginal costs. Application of the envelope theorem to (15) gives

$$\begin{aligned}
 -\frac{\partial V_C^*}{\partial n} &= -E(MU)_C \theta E\left(\frac{\partial m}{\partial \theta}\right) \\
 &+ \sum_i \left\{ p_i \left[\int_{II_C} U'(\cdot) m(\epsilon_i) dF_i(\epsilon_i) + B \int_{III_C} U'(\cdot) dF_i(\epsilon_i) \right] \right\} .
 \end{aligned} \tag{18}$$

When first-order condition (16) is substituted into (18), we get

$$-(\partial V_C^* / \partial n) = E(MU)_C E(m) > 0 . \tag{19}$$

The envelope result for an advance in a yields

$$-\frac{\partial V_C^*}{\partial a} = E(MU)_C \theta E(m) - (1 - \theta) \frac{\partial m}{\partial \theta} \tag{20}$$

$$+ (1 - \theta) \sum_i \left\{ p_i \left[\int_{II_C} (U'(\cdot)) m(\epsilon_i) dF_i(\epsilon_i) + B \int_{III_C} (U'(\cdot)) dF_i(\epsilon_i) \right] \right\} .$$

Substitution of (16) into (20) gives

$$-(\partial V_C^* / \partial a) = E\{MU\}_C E(m) > 0 . \quad (21)$$

Not only do technical advances that reduce n and a raise equilibrium consumer welfare, but (19) and (21) show that advances in n and a are perfect substitutes just as in a full information world. This is interesting since the CI contract insures a fraction of direct costs but no indirect costs. What happens is that the equilibrium θ adjusts in an asymmetric fashion to changes in n and a , respectively. The asymmetry is exactly that required so that marginal changes in n and a have identical effects on V_C^* . This asymmetry between $(\partial \theta^* / \partial n)$ and $(\partial \theta^* / \partial a)$ also brings about the equalities $(\partial \bar{H}_C^* / \partial n) = (\partial \bar{H}_C^* / \partial a)$ and $(\partial r_C^* / \partial n) = (\partial r_C^* / \partial a)$, where star superscripts indicate competitive equilibrium values.⁸

Partial effects of n and a on θ^* are found from differentiation of (16).⁹ We obtain $(\partial \theta^* / \partial n) = D_\theta^{-1}(-D_n)$ and $(\partial \theta^* / \partial a) = D_\theta^{-1}(-D_a)$, where D_j refers to the partial derivative of the left hand side of (16) with respect to j . Differentiation shows that $D_a - D_n = (\theta/a)D_\theta$. Therefore,

$$\frac{\partial \theta^*}{\partial n} - \frac{\partial \theta^*}{\partial a} = \frac{\theta^*}{a} . \quad (22)$$

The partial effect of n on m can be broken into a θ -constant effect and an effect transmitted through the change in the equilibrium value of θ :

$$\frac{\partial m}{\partial n} = \frac{\partial m}{\partial n} \Big|_{\bar{\theta}} + \frac{\partial m}{\partial \theta} \frac{\partial \theta^*}{\partial n} . \quad (23)$$

The partial effect of a can likewise be broken into two parts. It follows that

$$\frac{\partial m}{\partial n} = (G''')^{-1} \left[1 - a \frac{\partial \theta^*}{\partial n} \right] = (G''')^{-1} \left[1 - \theta^* - a \frac{\partial \theta^*}{\partial a} \right] = \frac{\partial m}{\partial a} \quad (24)$$

for $\epsilon_i \in II_C$, and $(\partial m / \partial n) = (\partial m / \partial a) = 0$ for $\epsilon_i \in I_C$ or III_C . The first equality in (24) follows from (23), (14), and the definition of C_θ ; the second equality follows from (22); the final equality follows from the analog to (23) with respect to a , (14), and the definition of C_θ .

Equality (24) establishes that the equilibrium insured fraction (θ^*) responds to technical changes in n or a such that the two types of change are perfect substitutes in their effects on consumption of medical treatment. Since average health depends on medical consumption, advances in n and a also are perfect substitutes in their effects on health. The effects on the equilibrium premium are also symmetric. Zero expected profits implies

$$r^* = \theta^* a E(m) . \quad (25)$$

$$\frac{\partial r^*}{\partial n} = \theta^* a \frac{\partial E(m)}{\partial n} + a E(m) \frac{\partial \theta^*}{\partial n} = \theta^* a \frac{\partial E(m)}{\partial a} + \theta^* E(m) + a E(m) \frac{\partial \theta^*}{\partial a} = \frac{\partial r^*}{\partial a} \quad (26)$$

where the first equality follows from (25), the second equality follows from (24) and (22), and the final equality follows from (25).

It seems worthwhile to reiterate the meaning of these perfect substitute results. Even though CI contracts only pay for direct medical costs, a technical advance that reduces an uncovered cost — such as unpleasant side effects of therapy or time lost in obtaining treatment — will have identical

effects on welfare, health, and premiums as a technical advance that reduces a covered cost – such as a doctor's fee or laboratory charge – by the same dollar amount. This result is due to the fact that the equilibrium coinsurance rate changes asymmetrically in response to the two types of technical change such that their net effects are identical.

Advances in the technical boundary (B) can actually reduce consumer welfare. Goddeeris (1984) first pointed out that technical advances could reduce welfare in CI arrangements. In the context of my parameterization of technology, the possibility of such a perverse effect can be attributed to advances in B but not to advances that reduce n or a . For the welfare effects of an advance in B , apply the envelope theorem to (15) to obtain

$$\frac{\partial V_C^*}{\partial B} = \sum_i \left\{ p_i \left[\int_{III_C} (U'(\cdot) \lambda(\epsilon_i)) dF_i(\epsilon_i) \right] \right\} - E(MU)_C^{\theta a} \sum_i \left\{ p_i \int_{III_C} dF_i(\epsilon_i) \right\}, \quad (27)$$

where $\lambda(\epsilon_i)$ is the multiplier from (13) and equals the difference between the marginal value of treatment (G') and the net cost per unit faced by the insured patient (C_θ). The first term in (27) is the expected marginal utility from an increase in B and is strictly positive if B represents a binding constraint for a non-zero measure of illness states. The second term in (27) is negative and leaves the sign of $(\partial V_C^*/\partial B)$ generally ambiguous. The latter term is the change in expected marginal utility due to the increased premiums implied by the increment in B . See Table A1 of Appendix B for a worked example that demonstrates both sign possibilities for (27).

The possibility that an advance in B will reduce consumer welfare depends upon the existence of illness shocks such as ϵ'' in figure 1. The proof of this result appears in Appendix A. The crucial characteristic of realizations such as ϵ'' is that in a full information contract the treatment level would

be strictly less than B while in the coinsurance contract the treatment of ϵ'' is limited by B . The shaded triangle in figure 1 represents the social loss due to the inefficient overuse of medical care due to moral hazard (given $\epsilon = \epsilon''$) presented in Pauly (1968). With shocks such as ϵ'' , an increase in B will increase the moral hazard loss. Since (27) can only be negative if there is a positive probability of shocks such as ϵ'' , it follows that the possibility for $(\partial V_C^*/\partial B)$ to be negative stems from the fact that an increase in B effects an increase in moral hazard losses at the margin.

The consumer welfare criterion for adoption of a new technology can lead to changes that are not Pareto health improving. In cases in which (27) is positive, an example like that provided in the full information discussion illustrates the point. When (27) is negative, adopted technologies can again make some patients worse off. Consider a proposed technology with B lower than its values in the current technology. The proposed technology would be adopted since this would raise consumer welfare; however, the health of patients with relatively severe illnesses (those with $\epsilon_i \in III_C$) would decline.

Unlike the full information case, a PHI adoption criterion can lead to declines in consumer welfare. This can occur iff (27) is negative and $\partial \theta^*/\partial B \geq 0$. (Table A1 of Appendix B shows a worked example that displays this sign combination.) In this case consider $T^1 = (n^0, a^0, B^1)$ versus $T^0 = (n^0, a^0, B^0)$ with $B^1 > B^0$. New technology T^1 will be adopted since patients with $\epsilon_i \in III_C$ will receive more care and no patients receive less; however, consumer welfare will decline. Intuitively, the new technology allows extended treatment for the seriously ill, but premiums rise to such an extent that consumers are worse off.

V. Prepaid Health Plan

In recent years health maintenance organizations (HMOs) have made significant inroads into the medical insurance market. HMOs represent a form of medical insurance contract different from conventional plans. In the context of the model here, the insurer is the HMO management. Management uses financial pressures and other incentives to encourage the HMO's doctors to keep total costs under control. A typical complaint about HMOs is that management gets in the way of appropriate treatment and that unusually complicated cases are under-treated since the doctor could not justify high treatment levels to management. A similar complaint is made about the prospective payment system (PPS) of Medicare hospital insurance. Under PPS the payment to the hospital from the insurer is conditioned on diagnosis. There are approximately 470 diagnosis-related groups among which a patient is categorized.

This section analyzes a stylized model of an HMO. Information is asymmetric. The insurer can verify diagnosis (i) but cannot observe severity (ϵ_i). The conditional distributions $F_i(\epsilon_i)$ are common knowledge. The insurer pays all direct medical costs in exchange for a prepaid premium.

I model the control exerted by HMO management in a simple fashion that captures a common criticism of these organizations. Management sets a maximum amount of medical treatment (\hat{m}_i) that an HMO doctor may prescribe conditional on the diagnosis. The \hat{m}_i will generally differ across i . I continue to assume that the doctor acts as a perfect agent for the patient, but the doctor will sometimes be confined by the limits set by management. Clearly, more severe cases within a diagnosis category, those with relatively high values of ϵ_i conditional on i , are more likely to be constrained by management's limits.

This model is really a worst case model for an HMO since it rules out the possibility that the doctor (and management) will allow overruns on some cases to be balanced by underruns on others. The results of this section may be contrasted with the best case HMO model – the full information world of Section III.

Begin with the ex post problem of a patient who has received illness shock ϵ_i . The problem is

$$\begin{aligned} \max_m U(y - r + G(\hat{H} - \epsilon_i + m) - nm) \\ \text{subject to } m \leq \hat{m}_i \text{ and } 0 \leq m \leq B . \end{aligned} \quad (28)$$

The necessary conditions for a maximum with $m > 0$ are

$$\begin{aligned} [G'(\cdot) - n] + \mu(\epsilon_i) + \lambda(\epsilon_i) = 0, \quad \mu(\epsilon_i) \geq 0, \quad \lambda(\epsilon_i) \geq 0, \\ \mu(\epsilon_i) [\hat{m}_i - m(\epsilon_i)] = 0, \quad \lambda(\epsilon_i) [B - m(\epsilon_i)] = 0, \end{aligned} \quad (29)$$

where $\mu(\epsilon_i)$ and $\lambda(\epsilon_i)$ are Kuhn-Tucker multipliers of the management constraint and of the technical boundary constraint, respectively.

If $\hat{m}_i < B$, then consumption of medical treatment is

$$m(\epsilon_i) = \begin{cases} 0 & \text{if } \epsilon_i \in I_{Mi} \\ \epsilon_i + G'^{-1}(n) - \hat{H} & \text{if } \epsilon_i \in II_{Mi} \\ \hat{m}_i & \text{if } \epsilon_i \in III_{Mi} \end{cases} \quad (30)$$

where $I_{Mi} = \{\epsilon_i | 0 \leq \epsilon_i \leq \hat{H} - G'^{-1}(n)\}$, $II_{Mi} = \{\epsilon_i | \hat{H} - G'^{-1}(n) \leq \epsilon_i \leq \hat{H} - G'^{-1}(n) + \hat{m}_i\}$, and $III_{Mi} = \{\epsilon_i | \hat{H} - G'^{-1}(n) + \hat{m}_i \leq \epsilon_i\}$.¹⁰ If $\hat{m}_i \geq B$, replace \hat{m}_i by B in (30) and in the definitions of II_{Mi} and III_{Mi} .¹¹ Figure 2 depicts demand

for treatment at three different illness severities under the assumption that $\hat{m}_i < B$. At low severity level ϵ^{\prime} , treatment is higher in the HMO plan than the other two forms. At moderate severity level $\epsilon^{\prime\prime}$, HMO consumption is less than CI consumption but greater than the full information level. At high severity level $\epsilon^{\prime\prime\prime}$, HMO consumption is lower than under the other two contract types. Since patients only pay indirect costs in the HMO contract, ex post conflicts between the patient/doctor and HMO management will occur at the higher severity levels - those at which \hat{m}_i is binding. For diagnoses in which $B < \hat{m}_i$, there is no such conflict between the patient/doctor and management because the limits of available technology, rather than management, are the binding constraints on treatment.

The competitive equilibrium prepaid (HMO) contract sets treatment limits conditional on diagnosis such that consumers' expected utility is maximized subject to zero expected economic profits for the health plan:

$$\max_{\{\hat{m}_i\}_{i=1}^N} p_0 U(y - r + G(\hat{H})) + \sum_i \left\{ p_i \left[\int (U(y - r + G(\hat{H} - \epsilon_i + m(\epsilon_i))) - nm(\epsilon_i)) dF_i(\epsilon_i) \right] \right\} \quad (31)$$

$$\text{subject to } r - aE\{m\} = 0,$$

where $m(\epsilon_i)$ is given by (30). Since it is not technically possible to provide more than B units of treatment, I will also append

$$\hat{m}_i \leq B \quad \text{for all } i \quad (32)$$

to (31). The first-order conditions for the equilibrium contract are

$$-E\{MU\}_M \lambda p_i \left[\int_{III_{Mi}} dF_i(\epsilon_i) \right] + p_i \left[\int_{III_{Mi}} \{U'(\cdot) [G'(\hat{H} - \epsilon_i + \hat{m}_i) - n]\} dF_i(\epsilon_i) \right] - \nu_i = 0, \quad (33)$$

$$\nu_i \geq 0, \nu_i[B - \hat{m}_i] = 0, \text{ for all } i,$$

where $E(MU)_M$ is expected marginal utility in the HMO equilibrium and ν_i is a multiplier that is active if the technical boundary is binding. Assume that second-order conditions are satisfied. Conditions (33) imply that

$$\frac{p_i \left[\int_{III_{Mi}} (U'(\cdot)) [G'(\cdot) - n] dF_i(\epsilon_i) \right]}{p_j \left[\int_{III_{Mj}} (U'(\cdot)) [G'(\cdot) - n] dF_j(\epsilon_j) \right]} = \frac{p_i \int_{III_{Mi}} dF_i(\epsilon_i)}{p_j \int_{III_{Mj}} dF_j(\epsilon_j)}, \quad i \neq j, \quad (34)$$

when B is not binding on either \hat{m}_i or \hat{m}_j . This says that the ratio of the expected marginal utilities from increasing the respective limits equals the ratio of the probabilities that a consumer will hit the respective limits. Different treatment limits across diagnoses depend on differences in conditional severity distributions and not on differences in the underlying probabilities of the diagnosis. That is, if i and j have the same severity distributions ($F_i(\epsilon) = F_j(\epsilon)$ for all ϵ), but i occurs twice as often as j ($p_i = 2p_j$), then \hat{m}_i will equal \hat{m}_j . These comments only apply if B is not binding on either disease. If B were strictly binding on \hat{m}_i but not on \hat{m}_j , then the equality in (34) is replaced with the "greater than" inequality.

The equilibrium HMO contract displays a different relationship between consumer welfare and technical advances than the two previous contracts. Unlike either of the previous cases, it is possible that an advance that reduces n may decrease consumer welfare (V_M^*). Application of the envelope theorem to (31) gives

$$-(\partial V_M^* / \partial n) = E(MU)_M \frac{\partial m}{\partial n} + E(U'(\cdot)m) \quad (35)$$

which is generally ambiguous in sign. Table A2 of Appendix B shows a worked example that demonstrates both sign possibilities for (35). Once again we see

that a perverse effect of technical advance on consumer welfare depends on the potential for an increase in the moral hazard triangle of inefficiency. It is the existence of patients whose medical consumption responds to a change in n (those with $\epsilon_i \in \Pi_{Mi}$) that makes the welfare reduction effect possible. Only if $E(\partial m/\partial n)$ in (35) is strictly negative can welfare fall when n falls. This depends on a positive probability of severity draws like ϵ' in figure 2. In such cases, a fall in n will increase m and may increase the shaded moral hazard loss triangle in figure 2.¹² HMOs can actually be less appealing to consumers if a new technology reduces unwanted side effects from medical treatment. The reason is that the side effects are one of the prices patients face for treatment. If price falls, inefficient overuse (reflected in premiums) may rise so much that the HMO's appeal falls.

An advance that reduces direct treatment costs will increase welfare. The envelope result gives

$$-(\partial V_M^*/\partial a) = E\{MU\}_M E\{m\} > 0 . \quad (36)$$

In an HMO the reduction in direct treatment costs has no first-order effect on the price faced by patients but does reduce premium costs. Consumer welfare rises just as in the contracts studied earlier.

Unlike the CI case, a technical advance in B cannot decrease HMO consumer welfare. This is intuitively obvious, because, by setting the \hat{m}_i appropriately, the HMO management can (and will) always rule out extensions in potential treatment that would decrease V_M^* . Application of the envelope theorem to the Lagrangean formed for (31) subject to (32) proves the point:

$$\partial V_M^*/\partial B = \sum_i \nu_i \geq 0 . \quad (37)$$

As in the previous cases, the consumer welfare adoption criterion can lead to the adoption of new technologies that imply lower health for some patients. For example, let $T^0 = (n^0, a^0, B^0)$ and $T^1 = (n^0 + dn, a^0 - da, B^0)$. The inequality

$$E(MU)_M E(m) da > \left[E(MU)_M a E\left(\frac{\partial m}{\partial n}\right) + E(U'(\cdot)m) \right] dn \quad (38)$$

will guarantee that $V_M^*(T^1) > V_M^*(T^0)$. Inequality (38) holds if either the term in square brackets is less than or equal to zero or if dn is set sufficiently small for given da . Patients with $\epsilon_i \in II_M$ see a decline in their health since the increase in n decreases their demand for treatment.

The Pareto health improving adoption criterion can sometimes lead to adoption of a technology that reduces consumer welfare. For example, consider a new technology that offers a lower n when (35) is negative and when $-(\partial \hat{m}_i^* / \partial n)$ is positive. (This possibility appears in the worked example in Table A2 of Appendix B.) The new technology meets the PHI criterion since patients in set II_M increase treatment and health while no other patients receive less treatment. However, consumer welfare falls since (35) is negative.

VI. Concluding Comments

This paper uses a three-parameter description of aggregate medical technology to assess the impact of different types of technical change. Effects vary across the different types of insurance contract studied here, and the different contracts have different informational requirements. The full information contract displays unambiguous and expected properties -

technical advance in any of the three facets of technology will increase consumer welfare and expected health. The coinsurance case, in which the illness shock is observed by the patient and doctor but not by the insurer, has the equilibrium property that advances in the boundary of feasible treatment can *decrease* welfare. A prepaid HMO-type of health plan, in which diagnosis but not actual severity is common knowledge, has the equilibrium property that reductions in the indirect costs of treatment to patients can *decrease* welfare.

There are also similarities across contract types. Technical advances that reduce the direct ("billing") cost per unit of treatment will always increase equilibrium consumer welfare. If consumer welfare is the standard in decisions to change technologies, then it will sometimes be the case that some types of patients are worse off when technology is changed - this can happen with any of the three contract forms.

The implications of two different criteria for adoption of a new technology were studied, and some comments are in order as to which of these criteria is more realistic. The consumer welfare criterion is applicable either to centrally planned economies in which the planner is both well informed and uses just such a criterion, or to competitive economies in which competition among insurers brings forth only those new technologies that are preferred by consumers. Failure to meet this criterion may be a practical difficulty for traditional coinsurance plans. Policies that do not restrict insureds to particular hospitals or doctors may fall into disfavor with consumers if the theoretical possibility that technical advances may decrease welfare is true to reality. In fact, the recent inroads made by HMOs and Preferred Provider Organizations are entirely consistent with this. The Pareto Health Improving criterion stresses patient utility and applies to

economies in which there is a strong aversion to taking action that works to the detriment of any group of patients. This may apply if the political arena guides technological change and pro-patient groups form effective political lobbies.

The coinsurance and HMO models analyzed here represent two poles of medical insurance arrangements. In theory, a contract that combines the two control elements of these arrangements, adding the treatment limits of the HMO model to the cost sharing of the coinsurance model, will be at least as successful as the separate contract types. Such hybrids have begun to emerge - with some conventional insurers using various utilization controls and some HMOs requiring copayments.

Appendix A

Proof that a necessary condition for $(\partial V_C^*/\partial B) < 0$ is that there exists a strictly positive probability for draws of ϵ_i such that B is binding under coinsurance but would not be binding under full information.

One such draw of ϵ_i is depicted by ϵ'' in figure 1. I will prove the result by showing that if \bar{p} a strictly positive probability of draws of ϵ_i such as ϵ'' in figure 1, then $(\partial V_C^*/\partial B) > 0$.

Proof: By assumption the set $III_C^* \equiv III_C \setminus III_F$ has zero probability measure. In other words the only values for which B is binding under coinsurance are values of ϵ_i in set III_F (i.e., values for which B would also be binding under full information). From (27) and the assumption above,

$$\frac{\partial V_C^*}{\partial B} = \sum_i \left\{ p_i \left[\int_{III_F} (U'(\cdot) [G'(\cdot) - C_\theta]) dF_i(\epsilon_i) \right] \right\} - E(MU)_C \theta a \sum_i \left\{ p_i \int_{III_F} dF_i(\epsilon_i) \right\}. \quad (A1)$$

Since under coinsurance one is ex post worse off the larger is one's draw of ϵ_i , it follows from concavity of $U(\cdot)$ that $E(MU)_C < \int_{III_F} U'(\cdot) dF_i(\epsilon_i)$. Thus,

$$\begin{aligned} & \int_{III_F} U'(\cdot) dF_i(\epsilon_i) - E(MU)_C \int_{III_F} dF_i(\epsilon_i) \\ & > \int_{III_F} U'(\cdot) dF_i(\epsilon_i) - \left\{ \int_{III_F} U'(\cdot) dF_i(\epsilon_i) \int_{III_F} dF_i(\epsilon_i) \right\} > 0. \quad (A2) \end{aligned}$$

From the definition $C_\theta \equiv n + (1 - \theta)a$ and use of (A2), (A1) implies that

$$\frac{\partial V_C^*}{\partial B} > \sum_i \left\{ p_i \left[\int_{III_F} (U'(\cdot) [G'(\cdot) - (n+a)]) dF_i(\epsilon_i) \right] \right\} \geq 0 . \quad (A3)$$

The first inequality in (A3) follows when the definition of C_θ is used in (A1) and coupled with (A2). The second inequality in (A3) follows from the fact that $[G'(\cdot) - (n+a)] \geq 0$ for $\epsilon_i \in III_F$. Q.E.D.

Appendix B

A worked example serves to demonstrate several of the sign possibilities claimed in the text. Assume the following: $U(x) = e_0x - \frac{1}{2}e_1x^2$, where $e_0 - e_1x > 0$; $G(H) = (b_0/b_1)H - (1/2b_1)H^2$, where $(b_0/b_1) - (1/b_1)H > 0$; and $\hat{H} = 0$. Assume that $p_0 = 0$ and that there is one disease with two different severity possibilities: $\text{Prob}(\epsilon = 1) = \text{Prob}(\epsilon = 2) = 1/2$. Tables A1 and A2 demonstrate cases with equilibrium coinsurance and equilibrium HMO contracts, respectively. All cases were checked to make sure that consumers would prefer the equilibrium insurance contract over no insurance.

Table A1 shows how the equilibrium values of θ^* , $(\partial V_C^*/\partial B)$, and V_C^* respond to changes in technical parameter B . Both possible signs of $(\partial V_C^*/\partial B)$ are demonstrated as we move to different values of B . The final four rows of the table show V_C^* falling in B while θ^* is rising in B . This is the sign combination in which the PHI adoption criterion is inconsistent with the consumer welfare criterion.

Table A2 shows how the equilibrium values of \hat{m}^* , $-(\partial V_M^*/\partial n)$, and V_M^* respond to declines in technical parameter n and to other changes. The first four rows demonstrate cases where V_m^* falls as n falls, and the final two rows show cases in which V_M^* rises as n falls. Also, the first four rows show \hat{m}^* rising as n falls while $-(\partial V_m^*/\partial n) < 0$. This is a case in which the PHI adoption criterion is not consistent with the consumer welfare criterion.

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Footnotes

1. In the worst case HMO model, the doctor acts in his patient's interest subject to the constraints set by HMO management.
2. The Stieltjes integral is used throughout.
3. I have assumed that $G'(\hat{H}) < C$. This ensures that the constraint $m(\epsilon_i) \leq \epsilon_i$ is never binding. It is quite simple to extend the analysis to the alternative case, but I will omit the extension here.
4. Assume that subset III_F has non-zero measure.
5. Analogous to n. 3, I assume that $G'(\hat{H}) < C_\theta$ so the constraint $m(\epsilon_i) \leq \epsilon_i$ is not binding.
6. Since equation (14) gives the unique solution to the patient's ex post problem, it can be used directly in solving problem (15). This method avoids the difficulties with the so-called "first-order approach" to the principal-agent problem explained in Grossman and Hart (1983) and Rogerson (1985).
7. It is assumed that subset II_C has non-zero measure.
8. This perfect substitute result generalizes to non-linear cost functions. Consider technologies of the form $T = (\nu, \alpha, B)$ where ν and α are parameters

influencing the indirect and direct costs of m , respectively. Let the total cost of treatment level m be $C(m) = \nu K(m) + \alpha K(m)$ with $K(0) = 0$, $K' > 0$, and $K'' \geq 0$. This will alter equations (12) through (17); however, changes in ν and α will be perfect substitutes in affecting V_C^* . It can be shown that $-(\partial V_C^* / \partial \nu) = -(\partial V_C^* / \partial \alpha) = E(MU)_C E(K(m)) > 0$.

9. In calculating the derivatives one must recognize that $r = \theta a E(m)$ by the zero expected profit condition in (15) and also that $m(\epsilon_i)$ is given by (14).

10. I assume that $G'(\hat{H}) < n$. This implies that, as in notes 3 and 5, the constraint $m(\epsilon_i) \leq \epsilon_i$ will not be binding.

11. I assume that the patient will not go outside of the HMO for medical treatment due to fixed costs of finding an outside doctor.

12. Changes in n will not reduce welfare if shocks are confined to those like ϵ'' in figure 2. When $\epsilon = \epsilon''$, \hat{m}_i is binding, and competitive managements would not change \hat{m}_i in a way that would reduce welfare.

Table A1
Equilibrium Coinsurance Simulation

B	θ^*	$(\partial v_C^* / \partial B)$	v_C^*
1.65	.168	0.0174	-.438
1.70	.174	0	-.437
1.75	.180	-0.0176	-.438
1.80	.186	-0.0350	-.439
1.85	.192	-0.0525	-.441
1.90	.198	-0.0700	-.444

Note - other assumptions: $e_0 = 0.5$, $e_1 = 1$, $b_0 = 1.5$, $b_1 = 1.9$, $y = 1$, $n = 0$,
and $a = 1$.

Table A2
Equilibrium HMO Simulation

n	b_1	a	\hat{m}^*	$-(\partial V_M^*/\partial n)$	V_M^*
.830	3	.300	.464	-.0445	-.2013
.825	3	.300	.478	-.0358	-.2015
.820	3	.300	.491	-.0276	-.2017
.810	3	.300	.517	-.0109	-.2018
.925	1.9	.175	1.511	1.2123	-.5623
.825	1.9	.175	1.700	1.2808	-.4371

Note - other assumptions: $e_0 = 0.5$, $e_1 = 1$, $b_0 = 1.5$, $y = 1$, and $B = 1.9$.

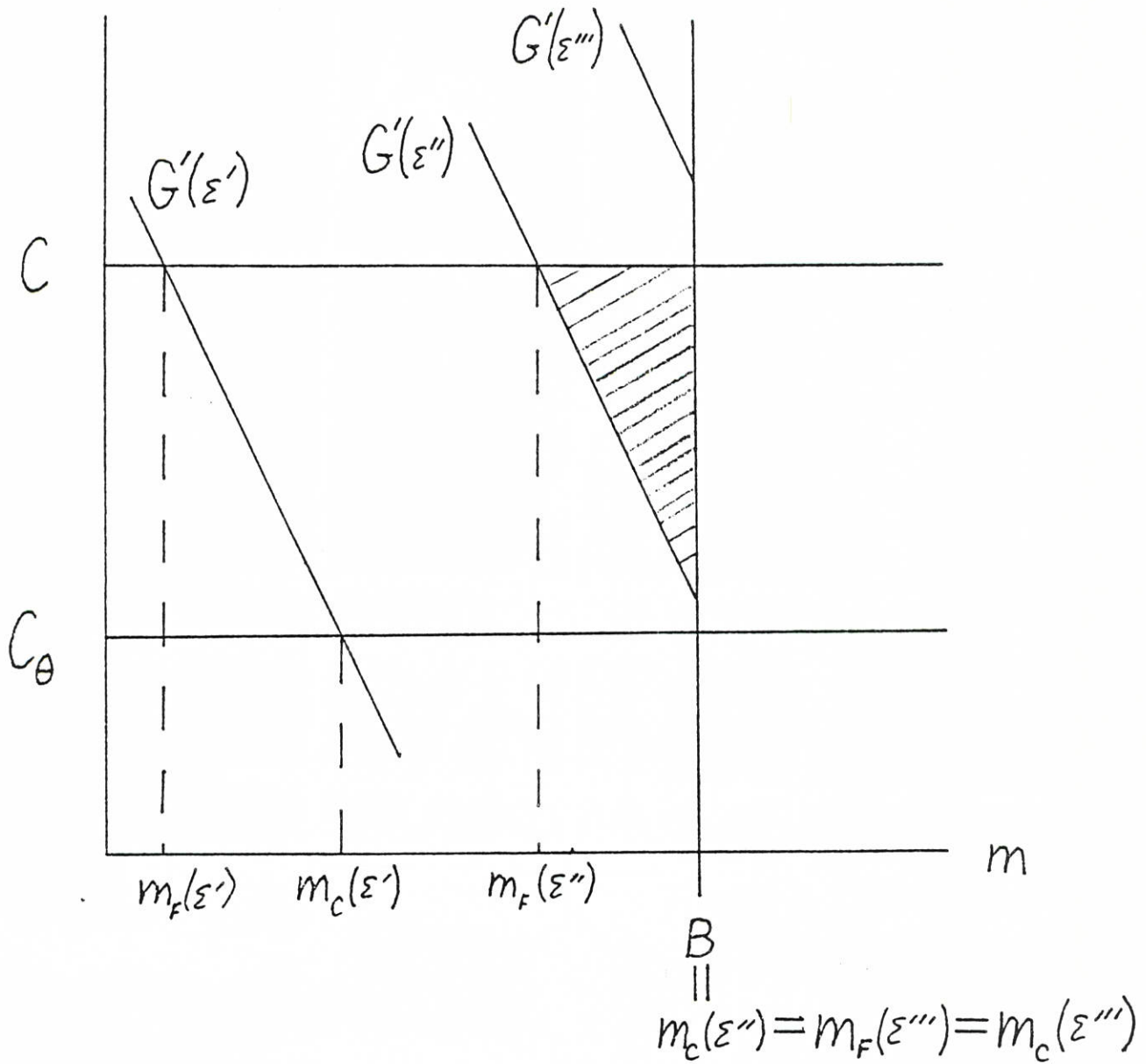


Figure 1

NOTES - $\varepsilon' < \varepsilon'' < \varepsilon'''$; $m_F(\cdot) \equiv$ a full information level;
 $m_C(\cdot) \equiv$ a CI level.

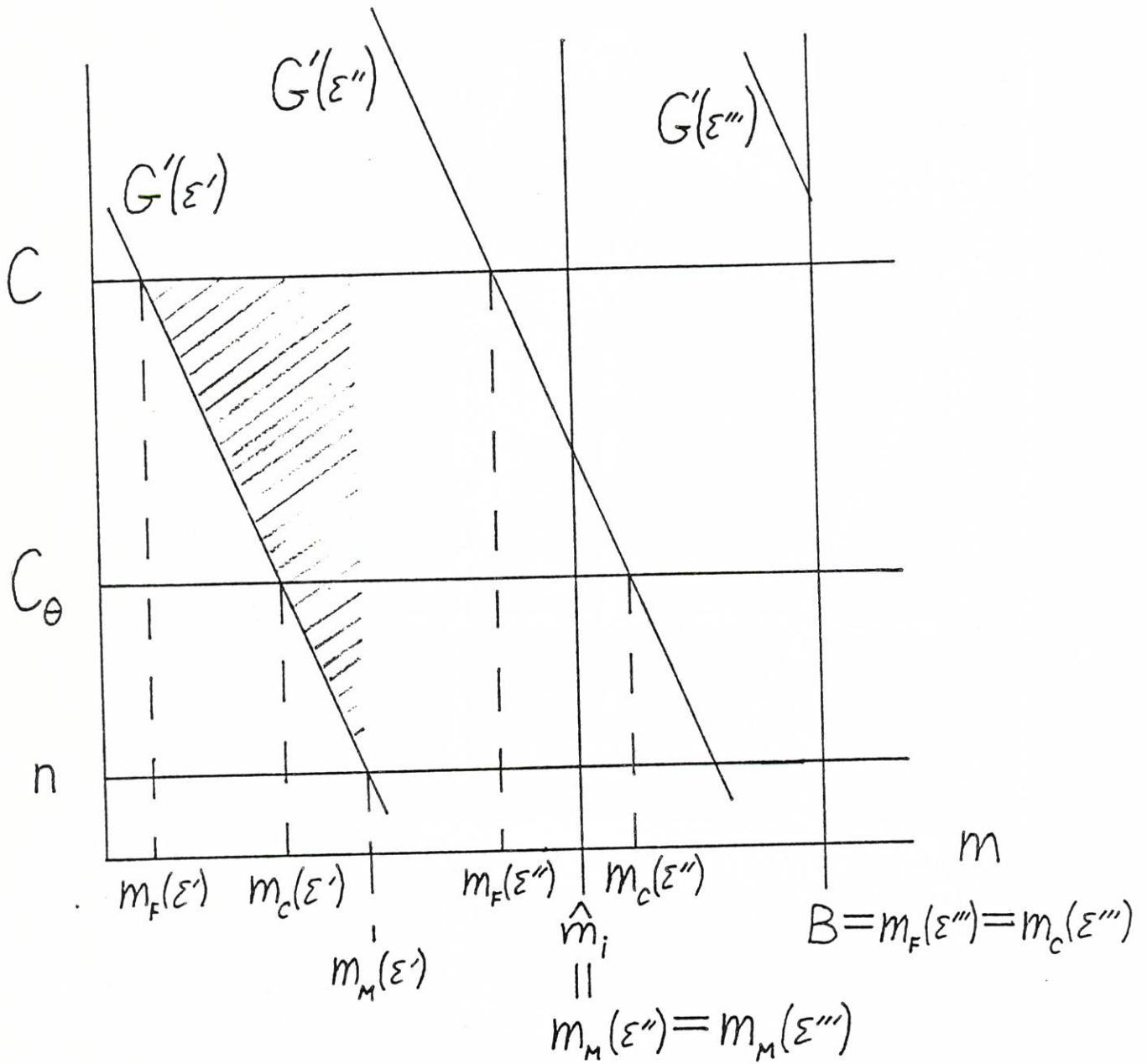


Figure 2

NOTES - $\epsilon' < \epsilon'' < \epsilon'''$; $m_F(\cdot) \equiv$ a full information level;
 $m_C(\cdot) \equiv$ a CI level; $m_M(\cdot) \equiv$ a HMD level.