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Abstract. We study the role of liability in disciplining an expert's behavior in a credence good market. The expert, who can provide two potential treatments for a consumer's problem, may misbehave in two ways: prescribing the "wrong" treatment given his private information, or failing to exert proper effort to diagnose the problem. We show that under a range of liability rules, the expert will choose the efficient treatment based on his information if the price margins for the two treatments are close enough. Moreover, a well-designed liability rule can motivate the expert to choose efficiently both the treatment and the diagnosis effort. This efficiency result continues to hold when the expert's diagnosis effort generates only a noisy signal about the nature of the consumer's problem, provided the signal is sufficiently informative.

Keywords: Credence goods, private information, diagnosis effort, undertreatment, overtreatment, liability

JEL Codes: D82, I18, K13, L23

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1. Introduction

Consider a market in which a consumer needs a treatment for a problem (e.g., a medical condition) from an expert (e.g., a physician). There can be two possible treatments, and the expert has private information about which is appropriate for the consumer. Given his information advantage, the expert may recommend to and provide the consumer with the "wrong" treatment, providing major treatment when only minor treatment is needed (*overtreatment*) or providing minor treatment when major treatment is necessary (*undertreatment*), if doing so increases his payoff. An extensive literature on credence goods has analyzed this adverse selection problem.[1] A prominent result from this literature is that equal price margin for the two treatments restores efficiency under adverse selection: the expert will recommend the appropriate treatment if he is made indifferent in his payoff between the two treatments.

In many cases, the expert may need to exert (additional) effort to determine the consumer's problem and the type of treatment that is appropriate. For example, when a patient complains about arrhythmia, it may indicate a minor problem that requires a minor treatment (e.g., follow-up checkups, possibly with some medication), but it may also signal a serious heart problem that requires surgery (a major treatment). The physician may need to exert (extra) effort —such as spending more time with the patient, investigating related symptoms, searching relevant information—to determine the

[1]See, e.g., Darby and Karni (1973), Taylor (1995), Emons (1997, 2001), Fong (2005), and Alger and Salanie (2006). Dulleck and Kerschbamer (2006) review this literature in a unified setup. Recent papers on credence goods include Liu (2011) that analyses a market with conscientious and selfish experts, Fong, Liu and Wright (2014) that study the impact of verifiability and liability on the expert's behavior, Dulleck and Wigger (2015) that model the services of politicians as credence goods, and Hilger (2016) that analyses the expert's behavior when the expert's treatment cost is private information.

type of treatment that is necessary. When the diagnosis effort and its cost are the expert's private information, he may not exert it even if doing so is efficient. This moral hazard problem, which has been largely ignored in the extant literature on credence goods,[2] can lead to additional market inefficiencies. In particular, while the equal price margin condition can remove the distortion due to adverse selection, it may also eliminate the incentive for the expert to exert effort to learn which treatment is appropriate for the consumer.

In this paper, we investigate the potential role of liability in disciplining the expert's behavior in a model that captures the market environments as described above. The consumer requires either a major or minor treatment depending on the type of her problem, and there is some common prior belief about the consumer type. Upon seeing the consumer, with a positive probability, the expert either immediately learns which treatment is appropriate (due to his expertise), or can exert (additional) costly private effort to obtain this information. After the treatment, for which the expert receives a fee from the consumer, if the consumer suffers from a wrong treatment, there is some probability that the consumer can find and verify the loss, in which case the expert is required to compensate the consumer according to some liability rule.

The existing literature on credence goods assumes that consumers are unable to learn whether the expert has recommended the appropriate treatment, at least in the case of overtreatment which, by assumption, solves the consumer's problem (e.g., Emons,1997, 2001; Fong, 2005; Dulleck and

[2] A recent paper by Bester and Dahm (2017) is a notable exception. They study a model of credence goods incorporating both adverse selection and moral hazard, focusing on the design of optimal contract when payment can be made contingent upon the consumer's report of her subjective evaluation of the treatment outcome.

Kerschbamer, 2006). Thus, the analysis in the literature presumes either infinite liability if undertreatment can be identified or no liability even if a consumer suffers from wrong treatment. We shall also call the expert services in our model "credence goods', but depart from the literature by assuming that the consumer may verify her loss with some positive probability when a wrong treatment is provided by the expert. What we have in mind are situations where both undertreatment and overtreatment can cause consumer loss. Even if the consumer cannot directly learn whether the appropriate treatment has been provided, she may find this information ex post—if she has suffered some loss—from other experts. The US federal government's recent effort in applying False Claims Act against overtreatment in medicare, for instance, suggests that a malpractice in medicare, which is typically considered as a type of credence good, can be discovered with a positive probability so that penalties may be imposed on providers who engage in overtreatment.[3]

We assume that liability for the expert can be a function of the losses from mistreatments and other commonly known parameters. The prices for the two treatments are assumed to be set to maximize consumer surplus, subject to a non-negative profit constraint for the expert. We find that for a wide range of liability rules, the equilibrium prices are such that the expert will receive the same expected profit—taking into account the expected liability

[3]Buck (2013) reported that "Exemplified by the Department of Justice's ongoing implantable cardioverter defibrillator investigation, the federal government is seeking to regulate overtreatment through application of its powerful anti-fraud statute." The federal government is reported to rely heavily on "data mining" to identify doctors who administer procedures differently from the majority. On the other hand, medical providers in the US are reported to form expert committees to identify commonly used procedures that are often clinically unnecessary and are highly expensive. See Brian Vastag, Doctors Groups Call for End to Unnecessary Procedures, Wash. Post (Apr. 4, 2012, 12:32 PM), http://www.washingtonpost.com/blogs/the-checkup/post/doctors-groups-call-for- end-to-unnecessary-procedures/2012/04/03/gIQAvrDptS_blog.html.

cost—from the two treatments under the prior belief. The price margins for the two treatments generally differ, but they are close enough to compel the expert to prescribe the appropriate treatment based on his best information. Remarkably, here the "equal price margin" condition is no longer required to solve the adverse selection problem, because the presence of liability relaxes the incentive constraint for the expert to reveal his private information truthfully. In fact, the familiar result that price margins are equalized for the two treatments emerges in equilibrium as a special case of our model under zero liability.

While there are many liability rules under which the expert will provide honest recommendation about the appropriate treatment, they generally do not provide the efficient incentive for the expert to exert diagnosis effort when needed. We show that there exists an optimal liability rule, together with the equilibrium prices it induces, that leads to the efficient effort choice and information disclosure by the expert. The optimal liability rule specifies a damage payment for a verified loss—contingent on whether the loss is due to overtreatment or undertreatment—that equates the price margin from each treatment to the efficient critical threshold of the expert's diagnosis cost. Then, in the event that the expert does not learn the nature of the problem upon seeing the consumer, he will choose to incur the additional cost to obtain this information if and only if it is efficient to do so; and the expert will recommend the appropriate treatment to the best of his knowledge, whether through the information upon seeing the consumer, from incurring the diagnosis cost, or using his prior belief if no updated information is obtained.

We further show that a well-designed liability rule also leads to the efficient outcome in the case that the expert can only obtain a noisy signal about the nature of the consumer's problem, provided the signal is sufficiently informative. However, if the signal is not sufficiently informative, the prices and liability that ensure truthful reporting of information by the expert can no longer induce the expert to exert the efficient effort.

Our paper contributes to the credence goods literature by analyzing a combined problem of adverse selection and moral hazard and exploring how liability can be used to possibly achieve both efficient diagnosis effort and honest recommendation of appropriate treatment. Dulleck and Kerschbamer (2009) investigate the incentives of experts to exert diagnostic effort and to report truthfully when the experts face competition from discounters and the consumers may free-ride on the expert's diagnosis effort and switch to cheaper services by discounters who can not perform diagnosis. They assume perfect verifiability in case of undertreatment and no verifiability in case of overtreatment. Bester and Dahm (2017) examine a combined problem that is similar to ours. They assume that the outcome of treatment is not verifiable and explore whether a payment scheme contingent upon the consumer's report of the treatment outcome can be used to implement efficiency.[4] Different from these papers, we assume that the outcome of either type of treatment is verifiable with some probability and analyze whether a liability rule can be designed to restore market efficiency.

We also contribute to the economic analysis of liability rules in different environments.[5] Daughety and Reinganum (1995, 2008), Spier (2011), Hua

[4]The papers by Demski and Sappington (1987) and Taylor (1995) consider costly diagnosis effort but assume treatment decisions are unobservable. Pesendorfer and Wolinsky (2003) analyse a model in which the experts need to exert diagnosis effort to discover the buyer's demand and show that the gathering of multiple opinions leads to underinvestment by the suppliers. There, it is assumed that the experts will report their private information truthfully.

[5]Brown (1973) and Shavell (1980) laid the foundation for the economic analysis of liabilities. See Shavel (2007) for a survey on more recent analysis of liabilities for accidents.

(2011), Chen and Hua (2012) analyze how liability rules affect a producer's incentive to improve product safety ex ante and the incentive to warn consumers or recalling a defective product ex post. The distinctive features of credence goods raise new issues and the optimal liability possesses very different properties. Simon (1982), Arlen and MacLeod (2005), Wright (2011) compare strict liability with negligence rule for medical malpractice. These models focus on the diagnosis effort aspect and ignore the adverse selection feature of credence goods, with the main result being that negligence rule is generally more effective than strict liability. But negligence rule is difficult to enforce in practice because it requires the determination of whether the expert has exercised due care, which is likely the expert's hidden action. In comparison, liability rules that are based on verified loss are easier to implement. Our analysis shows that a well designed liability rule can achieve the efficient outcome, in a setting where the expert needs to be provided with proper incentives both in exerting diagnosis effort and in recommending treatment.

In the rest of the paper, we describe our model in section 2. Section 3 conducts the analysis and presents our main results. In section 4, we extend our model to examine the case where diagnosis effort only leads to a noisy signal about the type of the consumer's problem. Section 5 offers concluding remarks, together with a discussion of the policy implications of our results.

2. The Model

A consumer needs a treatment from an expert for a problem that can be either minor or major, $t \in \{m, M\}$, where

$$\Pr(t = m) = \theta = 1 - \Pr(t = M) \in (0, 1). \tag{1}$$

The expert can provide two types of treatments, a minor treatment T_m or a major treatment T_M. A minor treatment (T_m) is appropriate if the consumer's problem is minor (m) while a major treatment (T_M) is appropriate if the problem is major (M). If the problem is not treated, the consumer suffers a loss x_t if the problem is type $t \in \{M, m\}$, with her expected loss without treatment as

$$x \equiv \theta x_m + (1 - \theta) x_M. \tag{2}$$

If the consumer receives a treatment from the expert, the consumer's gross utility, which depends on her type (t) and the treatment she receives, is

$$v(t, T) = \begin{cases} 0 & \text{if } t = m \text{ and } T = T_m \text{ or } t = M \text{ and } T = T_M \\ -z_u & \text{if } t = M \text{ and } T = T_m \\ -z_o & \text{if } t = m \text{ and } T = T_M \end{cases}. \tag{3}$$

Thus, the consumer's gross utility is normalized to zero if she receives the appropriate treatment for her problem. If the type is M but the treatment is T_m, *undertreatment* occurs and the consumer suffers a loss $z_u > 0$. On the other hand, *overtreatment* occurs when the type is m but the treatment is T_M, in which case the harm to the consumer is $z_o > 0$. We further assume that with probability $\alpha_u \in (0, 1]$, the consumer is able to verify her loss z_u

when undertreatment has occurred, and with probability $\alpha_o \in (0, 1]$ she is able to verify her loss z_o when overtreatment has occurred.

Note that the way we define consumer's utility is different from that in the literature. In the literature the harm from overtreatment is usually normalized to zero, and the consumer receives the same utility if her problem is resolved, whether it is resolved through proper treatment or overtreatment. Furthermore, undertreatment leads to the same utility as no treatment. (See, e.g. Emons, 1997, Dulleck and Kerschbamer, 2006). We depart from this modeling by assuming that overtreatment also leads to a harm for the consumer (we could allow $z_o = 0$ as a special case) and undertreatment may lead to a loss different from no treatment (with the two being equal as a special case). By adopting this more general setup, we wish to incorporate the increasing concern over the harm from overtreatment in practice. (See, for example, Brownlee, 2008; Buck, 2013, 2015.) It also allows us to analyze the role of liability in a more general and realistic setting.[6]

The expert is better informed about the nature of the consumer's problem, and, if necessary, can exert extra efforts to diagnose the problem. Specifically, we assume that upon seeing the consumer, with probability $\beta \in [0, 1)$ the expert is informed about the realization of t (i.e., whether $t = m$ or M), while with probability $1 - \beta$ he is not informed of t but privately learns the realization of k, his private cost for exerting some additional diagnosis effort to learn the realization of t.[7] Ex ante, k follows a continuous probability distribution $F(k)$ on support $\left[0,\ \bar{k}\right]$, with $\bar{k} > 0$. We denote the expert's decision on whether to incur k—if he does not observe the realization of t upon seeing the consumer—by $e \in \{E, N\}$. If he chooses E by incurring k,

[6]Our analysis and results would remain the same if we interpret z_u and z_o as the expected losses associated with undertreatment and overtreatment.

[7]This effort is beyond the observable normal effort associated with seeing the consumer.

the expert learns the realization of t, while if he chooses N (i.e., incurring no k) the expert maintains his prior belief about t. Whether the expert incurs the diagnosis cost is his private information.

Treatments T_m and T_M cost the expert 0 and $C > 0$, respectively, with

$$\text{(i) } C + \theta z_o < x, \qquad \text{and} \qquad \text{(ii) } C < z_u(1-\theta) \tag{4}$$

so that (i) it is not efficient to have no treatment, and (ii) without knowing whether $t = m$ or M, there exist parameter values under which T_M is more efficient than T_m. We assume that the type of treatment provided to the consumer is publicly observed (e.g., whether a certain procedure is carried out). Thus, if the expert recommends treatment T_M, cost C must be incurred to implement the treatment. The consumer is committed to undertaking the treatment recommended by the expert. That is, we assume "verifiability" and "commitment" in our model.[8]

The expert may be liable for a bad outcome that is a result of maltreatment. Specifically, we assume that the expert is required to pay damage $D_u > 0$ if it is verified that the consumer has received undertreatment with loss z_u, and he is required to pay damage $D_o > 0$ if it is verified that the consumer has received overtreatment with loss z_o.[9]

Let P_M and P_m be the prices for treatments T_M and T_m. The timing of the game, given a liability rule (D_u, D_o), proceeds as follows:

[8]See Dulleck and Kerschbamer(2006) for discussions on the assumption of verifiability and commitment.

[9]In the existing literature on credence goods, the assumption of "liability" typically refers to unlimited liability for undertreatment ($D_u = +\infty$). This, together with the assumption $z_o = 0$, deters undertreatment. Our more general formulation allows us to analyse the impact of different liabilities on the expert's behavior and the optimal liability rule.

1. The consumer sets prices (P_M, P_m) for the two types of treatments respectively.

2. Upon seeing the consumer, the expert either learns the realization of t and chooses $T \in \{T_m,\ T_M\}$, or, without learning t, he learns the realizations of his (additional) private diagnosis cost k. The expert chooses whether to exert diagnosis effort and the type of treatment to propose to the consumer.

3. The treatment recommended by the expert is implemented and payment (P_M or P_m) is made.

4. If a loss from treatment is *verified*, the expert compensates the consumer an amount according to the liability rule.

Notice that there are potentially four dimensions of asymmetric information in our model: the expert's private information about (i) whether he learns the realization of t upon seeing the consumer, (ii) the realization of k, (iii) whether he incurs the diagnosis cost, and (iv) whether $t = m$ or M, with or without incurring k.

3. Analysis

In this section, we first describe the efficient benchmark, then characterize the equilibrium of the game between the expert and the consumer, and finally identify the optimal liability rule that implements the efficient outcome.

3.1 Efficient Benchmark

Suppose there is a social planner who learns all the private information of the expert and can dictate the expert on what to be done in each case. If the expert learns t upon seeing the consumer, it is clearly efficient for him to choose T_i when $t = i$ for $i = m, M$. So we focus on the case where the expert needs to incur k if it is necessary to learn t. The total surpluses of the expert and the consumer from strategies (N, T_M) (implementing T_M without incurring diagnosis cost k) and (N, T_m) (implementing T_m without incurring cost k) are respectively

$$W(N, T_M) = -\theta z_o - C; \qquad W(N, T_m) = -(1-\theta) z_u. \tag{5}$$

Following an action E, the efficient choice for the expert is T_m if $t = m$ and T_M if $t = M$,. This strategy E_T leads to

$$W(E_T) = -k - (1-\theta) C.$$

By the assumption on C from part (i) of (4),

$$W(N, T_M) = -\theta z_o - C > -x,$$

so that if the expert has no additional information about t beyond his prior belief, a major treatment is better than no treatment. Moreover, $W(N, T_M) \geq W(N, T_m)$ if and only if

$$z_o \leq \frac{z_u(1-\theta) - C}{\theta} \equiv z_o^* \qquad \text{or} \qquad z_u \geq \frac{\theta z_o + C}{1-\theta} \equiv z_u^*. \tag{critical z}$$

That is, if the expert must choose the treatment based on his prior belief about t, it is efficient to choose T_M if the harm from overtreatment is relatively small compared to undertreatment ($z_o \leq z_o^*$), and to choose T_m otherwise. Notice that z_o^*, which is positive by the assumption on C from part (ii) of (4), is increasing in z_u and decreasing in C.

Incurring the diagnosis cost is efficient when $W(E_T) \geq \max\{W(N, T_M),\ W(N, T_m)\}$, which holds if and only if

$$k \leq \min\left\{\theta(C + z_o),\ \ (1-\theta)(z_u - C),\ \bar{k}\right\} \equiv k^*(z_o, z_u), \tag{6}$$

where we allow the possibility that $\bar{k}$ may be below $\min\{\theta(C + z_o),\ \ (1-\theta)(z_u - C)\}$.

Lemma 1 summarizes the efficient benchmark.

Lemma 1 *If the expert learns t upon seeing the consumer, it is efficient for him to choose T_i when $t = i$ for $i = m, M$. Otherwise: (i) If $k > k^*(z_o, z_u)$ and $z_o \leq z_o^*$, it is efficient to choose (N, T_M). (ii) If $k > k^*(z_o, z_u)$ and $z_o > z_o^*$, it is efficient to choose (N, T_m). (iii) If $k \leq k^*(z_o, z_u)$, it is efficient to choose E_T.*

Thus, when the expert is not informed about t upon seeing the consumer, the efficient decision by the expert depends straightforwardly on the realized value of k and on the value of z_o relative to z_o^*: When the diagnosis cost is sufficiently high, it is efficient to have T_M without incurring k if the loss from overtreatment is small enough, while it is efficient to have T_m without incurring k if the loss from overtreatment is high enough; when the diagnosis cost is sufficiently low, it is efficient to incur k and then chooses the appropriate treatment. Notice that when $k^*(z_o, z_u) = \bar{k}$, it is always efficient to incur the diagnosis cost.

3.2 Equilibrium of the Expert-Consumer Game

We now analyze the game between the expert and the consumer, taking the liability rule (D) as given. Without loss of generality, denote any pair of prices by

$$P_M = C + \Phi_M, \qquad P_m = \Phi_m, \tag{7}$$

where $\Phi_M \geq 0$ and $\Phi_m \geq 0$ are the price margins or markups for the expert if he provides treatments T_M and T_m, respectively, without accounting for potential diagnosis or liability costs. Each pair of prices—or equivalently (Φ_M, Φ_m)—posted by the consumer is followed by a treatment game between the expert and the consumer.

If the expert knows the realization of t, either upon seeing the consumer or after incurring k, it would be optimal for him to choose T_i when $t = i$ for $i = m, M$ *if and only if*

$$\Phi_M \geq \Phi_m - \alpha_u D_u, \qquad \Phi_m \geq \Phi_M - \alpha_o D_o. \tag{8}$$

Our analysis will proceed under the presumption that (8) holds—so that the expert will choose the appropriate treatment if he knows what t is—and we later confirm that this is indeed the case in equilibrium and a pair of prices that satisfy (8) is indeed optimal for the consumer.

Notice that for (8) to hold, $\Phi_M = \Phi_m$ if $D_u = D_o = 0$. That is, in order for the expert recommend the appropriate treatment given his information, equal price margins from different treatments are required when no liability can be imposed on the expert.[10] When there are positive liabilities, though $\Phi_M = \Phi_m$ is sufficient for (8), it is no longer necessary: as long as the price

[10] See, e.g., Dulleck and Kerschbamer, 2006.

margins for the two treatments are not too different, the expert will have the right incentive to recommend the appropriate treatment if he knows t. The presence of malpractice liability relaxes constraint (8).

Given (8), under which the expert will choose T_i for $t = i$ if he learns the realization of t upon seeing the consumer, we can focus our analysis on three strategies that the expert can choose from if he does not initially learn t: (i) (N, T_M): choosing T_M without incurring k. (ii) (N, T_m): choosing T_m without incurring k; and (iii) E_T: incurring k, followed by the choices of T_i when $t = i$ for $i = m, M$. For a given $D \equiv (D_u, D_o)$ and k, the expert's profits under each of these strategies are, respectively:

$$\pi(N, T_M) = \Phi_M - \theta\alpha_o D_o, \quad \pi(N, T_m) = \Phi_m - (1-\theta)\alpha_u D_u, \tag{9a}$$

$$\pi(E_T) = \theta\Phi_m + (1-\theta)\Phi_M - k, \tag{9b}$$

where $\theta\alpha_o D_o$ is the expert's expected liability payment to the consumer under (N, T_M), since overtreatment occurs with probability θ; and, similarly, $(1-\theta)\alpha_u D_u$ is the expert's expected liability payment to the consumer under (N, T_M). The expert will make his choice to maximize his expected payoff; when he has the same expected payoff from any two options, we assume that he will choose the option that is favorable to the consumer.

We further assume that the consumer is constrained to set a pair of prices satisfying

$$\pi(N, T_M) \geq 0, \qquad \pi(N, T_m) \geq 0, \tag{10}$$

so that the expert, whose outside option is zero profit, can receive non-negative expected profit from providing each treatment under the common prior about t. What we have in mind are situations where both the expert and the consumer have some pricing/bargaining power: the expert can insist on charging prices that would ensure non-negative profit for offering each treatment under the prior belief about t, whereas the consumer can offer prices subject to this constraint.[11]

Upon seeing the consumer, the expert either learns the realization of t and chooses $T \in \{T_m,\ T_M\}$, or, without learning t, he learns the realizations of his (additional) private diagnosis cost k and chooses his action from $\{(N, T_M), (N, T_m), E_T\}$.

In the treatment game following a pair of prices $\Phi \equiv (\Phi_M, \Phi_m)$, the expert's optimal strategy when he does not learn t upon seeing the consumer is E_T if and only if $\pi(E_T) \geq \max\{\pi(N, T_M), \pi(N, T_m)\}$, or k is sufficiently small:

$$k \leq \min\{\theta\,(\Phi_m - \Phi_M + \alpha_o D_o)\,,\ (1-\theta)\,(\Phi_M - \Phi_m + \alpha_u D_u)\} \equiv \hat{k}(D, \Phi). \tag{11}$$

When $k > \hat{k}(D, \Phi)$, the expert prefers strategy (N, T_M) to strategy (N, T_m) if and only if

$$\pi(N, T_M) - \pi(N, T_m) = \Phi_M - \theta\alpha_o D_o - [\Phi_m - (1-\theta)\alpha_u D_u] > 0. \tag{12}$$

On the other hand, the consumer surplus from the three strategies are respectively

$$S(N, T_M) = \theta\,[-z_o - \Phi_M - C + \alpha_o D_o] + (1-\theta)\,[0 - \Phi_M - C]\,, \tag{13}$$

$$S(N, T_m) = \theta\,[-\Phi_m] + (1-\theta)\,[-z_u + \alpha_u D_u - \Phi_m]\,, \tag{14}$$

$$S\,(E_T) = -\theta\Phi_m - (1-\theta)\,(\Phi_M + C)\,. \tag{15}$$

[11] Alternatively, we may assume that the consumer has a sufficiently high value to receive the "right" treatment in each state. Then, she indeed has the incentive to set prices satisfying (10), so that the expert is willing to provide the treatment.

Thus, consumer surplus is higher if Φ_m and Φ_M are lower in each case. We also note that

$$\begin{aligned} S(E_T) - S(N, T_M) &= \theta \left[\Phi_M - \Phi_m + C + z_o - \alpha_o D_o\right], &(16)\\ S(E_T) - S(N, T_m) &= (1-\theta)\left(\Phi_m - \Phi_M - C + z_u - \alpha_u D_u\right). &(17)\end{aligned}$$

The result below refers to condition

$$\alpha_u D_u + \alpha_o D_o \leq \min\left\{\frac{C + z_o}{1-\theta}, \ \frac{z_u - C}{\theta}\right\}. \tag{18}$$

Proposition 1 *In equilibrium, for any given $D = (D_u, D_o)$ satisfying (18), $\Phi = \hat{\Phi} = \left(\hat{\Phi}_M, \hat{\Phi}_m\right)$, where:*

$$\hat{\Phi}_M = \theta \alpha_o D_o, \qquad \textit{and} \qquad \hat{\Phi}_m = (1-\theta)\alpha_u D_u. \tag{19}$$

(i) If the expert learns t upon seeing the consumer, he will choose T_t for $t = m, M$. (ii) Otherwise, he will incur k if and only if $k \leq \hat{k}\left(D, \hat{\Phi}\right) = \theta(1-\theta)\left(\alpha_u D_u + \alpha_o D_o\right)$, and after incurring k the expert will choose T_t for $t = m, M$; while without incurring k he will choose T_M if $z_o < z_o^*$ and T_m if $z_o > z_o^*$.

Proof. Note that the price $\hat{\Phi}$ indeed satisfy (8) and is the lowest possible price satisfying (10). Suppose to the contrary that in equilibrium $\Phi = (\Phi_M, \Phi_m) \neq (\hat{\Phi}_M, \hat{\Phi}_m)$. Then, from (10), (Φ_M, Φ_m) must be such that $\pi(N, T_i) > 0$ for at least one i. We show that the consumer can then increase her expected surplus by choosing some different price, contradicting the optimality of (Φ_M, Φ_m) for the consumer.

Under (Φ_M, Φ_m), let $\pi(N, T_M) - \pi(N, T_m) = \Delta$. Then from (9),

$$\Phi_M - \Phi_m = \Delta + \theta \alpha_o D_o - (1-\theta)\alpha_u D_u. \tag{20}$$

From (11), if the expert does not learn t upon seeing the consumer, he will choose to incur k if and only if k does not exceed

$$\begin{aligned}
\hat{k}(D, \Phi) &= \min\left\{\theta\left(\Phi_m - \Phi_M + \alpha_o D_o\right), (1-\theta)\left(\Phi_M - \Phi_m + \alpha_u D_u\right)\right\} \\
&= \min\{\theta\left[-\Delta - \theta\alpha_o D_o + (1-\theta)\alpha_u D_u + \alpha_o D_o\right], \\
&\quad (1-\theta)\left[\Delta + \theta\alpha_o D_o - (1-\theta)\alpha_u D_u + \alpha_u D_u\right]\} \\
&= \min\left\{\theta\left[-\Delta + (1-\theta)\left(\alpha_o D_o + \alpha_u D_u\right)\right],\ (1-\theta)\left[\Delta + \theta\left(\alpha_o D_o + \alpha_u D_u\right)\right]\right\} \\
&= \begin{cases} \theta\left[-\Delta + (1-\theta)\left(\alpha_o D_o + \alpha_u D_u\right)\right] & \text{if } \Delta > 0 \\ (1-\theta)\left[\Delta + \theta\left(\alpha_o D_o + \alpha_u D_u\right)\right] & \text{if } \Delta < 0 \end{cases}.
\end{aligned}$$

We consider in turn two cases.

Case 1: $\Delta \neq 0$. If $\Delta > 0$, then $\pi(N, T_M) > \pi(N, T_m) \geq 0$ and the expert would choose T_M if he is not initially informed about t and also does not incur k. From (16) and (20):

$$\begin{aligned}
S\left(E_T\right) - S(N, T_M) &= \theta\left[\Phi_M - \Phi_m + C + z_o - \alpha_o D_o\right] \\
&= \theta\left[\Delta + \theta\alpha_o D_o - (1-\theta)\alpha_u D_u + C + z_o - \alpha_o D_o\right] \\
&= \theta\left[\Delta + C + z_o - (1-\theta)\left(\alpha_u D_u + \alpha_o D_o\right)\right] > 0.
\end{aligned}$$

The consumer prefers E_T to (N, T_M). Therefore, by reducing Φ_M slightly, Δ becomes smaller and $\hat{k}(D, \Phi)$ will rise—so that the expert incurs k more often while (8) continues to hold—and the consumer will also pay a lower expected price. Therefore this change increases the consumer's expected surplus. Thus, a pair of prices with $\Delta > 0$ is not optimal for the consumer.

If $\Delta < 0$, the expert would choose T_m if he is not initially informed about t and also does not incur k, and a similar argument shows

$$\begin{aligned} S(E_T) - S(N, T_m) &= (1-\theta)(\Phi_m - \Phi_M - C + z_u - \alpha_u D_u) \\ &= (1-\theta)\left[-\Delta + z_u - C - \theta(\alpha_u D_u + \alpha_o D_o)\right] > 0, \end{aligned}$$

and the consumer can increase her surplus by reducing Φ_m.

Moreover, if the expert learns t upon seeing the consumer, the reduction in Φ_M or Φ_m always increases consumer surplus given that (8) is satisfied.

Case 2: $\Delta = 0$. Then if $\pi(N, T_M) = \pi(N, T_m) > 0$, by lowering both Φ_M and Φ_m to the levels where $\pi(N, T_M) = \pi(N, T_m) = 0$, $\hat{k}(D, \Phi)$ is unchanged but the consumer will pay a lower expected price, which increases her surplus.

Combining with (10), we have shown (19) is the optimal choice of price for the consumer.

Next, from (11), the expert incurs k if and only if $k \leq \hat{k}\left(D, \hat{\Phi}\right) = \theta(1-\theta)\left[\alpha_u D_u + \alpha_o D_o\right]$. Since the $(\hat{\Phi}_M, \hat{\Phi}_m)$ from (19) satisfy (8), whether the expert learns t upon seeing the consumer or after incurring k, the expert will indeed choose T_t for $t = m, M$.

Finally, under (19), the expert receives the same expected profit from choosing (N, T_M) and (N, T_m). Hence it is an equilibrium for him to choose T_M if $z_o < z_o^*$ and T_m if $z_o > z_o^*$. Moreover, under $(\hat{\Phi}_M, \hat{\Phi}_m)$, from (13) and (14):

$$\begin{aligned} S(N, T_M) &= -\hat{\Phi}_M - C + \theta\alpha_o D_o - \theta z_o = -\theta\alpha_o D_o - C + \theta\alpha_o D_o - \theta z_o = -C - \theta z_o, \\ S(N, T_m) &= -\hat{\Phi}_m + (1-\theta)\alpha_u D_u - (1-\theta) z_u = -(1-\theta) z_u. \end{aligned}$$

Thus the consumer will prefer (N, T_M) to (N, T_m) if $z_o < z_o^*$ and prefer (N, T_m) to (N, T_M) if $z_o > z_o^*$. Therefore, since by assumption the expert will choose the action desired by the consumer when facing two actions that have the same expected payoff to him, the only equilibrium when $k > \hat{k}(D, \Phi)$ is for the expert to choose T_M if $z_o < z_o^*$ and T_m if $z_o < z_o^*$. ■

A few comments about the equilibrium are in order. First, in equilibrium the expert has the same (zero) expected profit in treatments T_M and T_m if he holds the prior belief about t. Notice that this result is obtained under the assumption that the consumer makes prices offers under the constraint that expert is able to earn a non-negative profit in each treatment without incurring k. Without the constraint that $\pi(N, T_t) \geq 0$ for $t = m, M$, the consumer may offer prices so that $\pi(N, T_t) < 0$ for at least one t. In that case, $\hat{k}(D, \Phi)$ will also become smaller such that the expert exerts less diagnosis effort. But the benefit from doing so is to receive a larger surplus (paying a lower price) in the case that the expert learns t upon seeing the consumer. If β is relatively small and the expert's diagnosis effort is important, choosing prices satisfying (10) will be optimal for the consumer.

Second, unlike the result in the literature, in our model the two treatments need not have equal price margins to induce the expert to choose the appropriate treatment when he knows the realization of t. Rather, the two treatments need to have the same expected profit—given the expected liability cost—under the expert's prior belief about t. Moreover, if the liability D_u or D_o is high enough so that (18) is violated, it might be to the advantage of the consumer that the expert does not learn the realization of t and provides the wrong treatment, in which case the consumer could collect the (excessively) high damage payment. Thus, if the liability is not properly designed, the equilibrium incentive could be perverse. This adverse situation will not arise if the liability satisfies (18), which induces price margins for the two treatments that are close enough to satisfy (8).

Third, for any given liabilities (D_o and D_u) satisfying (18), while the equilibrium prices will induce the expert to choose the efficient treatment given his information, whether under the prior belief about t or knowing the realization of t (possibly by incurring k), under these prices $\hat{k}(D, \hat{\Phi})$ will generally not equal to $k^*(z_o, z_u)$. Therefore the equilibrium generally does not lead to the efficient diagnosis decision. Notice also that the expert whose realized k is below $\hat{k}(D, \hat{\Phi})$ will receive positive profit—the information rent—in equilibrium.

3.3 Efficient Liability

In this subsection, we show that there exists a liability rule that would lead to the efficient outcome as described in Lemma 1.

Recall that under the equilibrium prices given in (19), inefficiency arises only when $\hat{k}\left(D, \Phi\right) \neq k^*\left(z_o, z_u\right)$, where

$$k^*\left(z_o, z_u\right) = \min\left\{\theta\left(C + z_o\right),\ (1-\theta)(z_u - C),\ \bar{k}\right\},$$

with $k^*\left(z_o, z_u\right) = \min\left\{\theta\left(C + z_o\right),\ \bar{k}\right\}$ if $z \leq z_o^*$ and $k^*\left(z_o, z_u\right) = \min\left\{(1-\theta)(z_u - C),\ \bar{k}\right\}$ if $z > z_o^*$. We can find an efficient liability rule that ensures $\hat{k}\left(D, \Phi\right) = k^*\left(z_o, z_u\right)$. Let $D^* = (D_u^*,\ D_o^*)$ be the efficient liability, and $(\hat{\Phi}_M, \hat{\Phi}_m) = (\Phi_M^*, \Phi_m^*)$ be the the equilibrium price margins under D^*.

Proposition 2 *The following liability rule results in the efficient outcome in equilibrium:*

$$D_u^* = \frac{k^*(z_o, z_u)}{(1-\theta)\alpha_u}, \qquad D_o^* = \frac{k^*(z_o, z_u)}{\theta\alpha_o}. \tag{21}$$

Proof. The liability under (21) satisfies (18), and hence in equilibrium the price margins satisfy (19), with $\Phi_M^* = \Phi_m^* = \min\left\{\theta(C+z_o), \ \bar{k}\right\}$ if $z_o \leq z_o^*$ and $\Phi_M^* = \Phi_m^* = \min\left\{(1-\theta)(z_u - C), \ \bar{k}\right\}$ if $z_o > z_o^*$. Note that under (D_u^*, D_o^*),

$$\begin{aligned}
\hat{k}(D^*, \Phi^*) &= \theta(1-\theta)\left(\alpha_u D_u + \alpha_o D_o\right) \\
&= \theta(1-\theta)\left(\alpha_u \frac{k^*(z_o, z_u)}{(1-\theta)\alpha_u} + \alpha_o \frac{k^*(z_o, z_u)}{\theta\alpha_o}\right) = k^*(z_o, z_u)
\end{aligned}$$

Thus, efficiency is achieved in equilibrium. ■

Notice that with the liability that implements the efficient outcome, the equilibrium price margin for each treatment is equal to the efficient critical k value, $k^*(z_o, z_u)$. Thus, while there exist a range of liabilities that would induce the equilibrium markups given in (19) for the two treatments and these markups generally differ, under the optimal liability they are the same.

Also notice that the efficient liability depends on $F(\cdot)$ only through $\bar{k}$, and is otherwise invariant with respect to the form of $F(\cdot)$. When $\bar{k} < \min\{\theta(C+z_o), \ (1-\theta)(z_u - C)\}$, it is always efficient for the expert to incur the diagnosis cost. The efficient liability in this case is

$$D_u^* = \frac{\bar{k}}{(1-\theta)\alpha_u}, \qquad \text{and} \qquad D_o^* = \frac{\bar{k}}{\theta\alpha_o},$$

both of which increase in $\bar{k}$, with $D_u^* \to 0$ and $D_o^* \to 0$ when $\bar{k} \to 0$. Intuitively, imposing a liability has a cost to the consumer, because the price for the expert's service will have to increase to cover the expected liability cost. Hence, when the expert can learn the nature of the problem with little additional diagnosis cost, the efficient liability also goes to zero.

When $k^*(z_o, z_u) < \bar{k}$, it is no longer always efficient to incur k. Then, if z_o is below a certain critical value (z_o^*), the efficient threshold k^* is $\theta\,(C + z_o)$, and the optimal liabilities for overtreatment and for undertreatment both increases in z_o, C and θ, which maintains the efficient incentive for the expert to exert the diagnosis effort. On the other hand, if $z_o > z_o^*$, the efficient threshold $k^*(z_o, z_u)$ is $(1-\theta)(z_u - C)$, and to maintain the expert's incentive to exert the diagnosis effort, D_o and D_u both increase in z_u but decrease in C, while D_o also decreases in θ.

Notice that the efficient D_o and D_u vary in the same direction as the relevant parameter values change, so that the relative profit margins from the two treatments are maintained.

The efficient liability can be expressed as a multiplier of the loss from undertreatment or overtreatment: $D_u = \gamma_u z_u$ and $D_o = \gamma_o z_o$, where

$$\gamma_u = \frac{k^*\left(z_o, z_u\right)}{(1-\theta)\alpha_u z_u}, \qquad \gamma_o = \frac{k^*\left(z_o, z_u\right)}{\theta\alpha_o z_o}. \tag{22}$$

Notice that when $\bar{k} \to 0$, both $\gamma_u \to 0$ and $\gamma_o \to 0$, while it's also possible that $\gamma_u > 1$ or $\gamma_o > 1$ (i.e., there can be punitive damages). Moreover, under the optimal liability, as the loss from overtreatment becomes more likely to be verified relative to the loss from undertreatment, the penalty for undertreatment will increase (in the sense that γ_u becomes higher relative to γ_o). However, since in general $\gamma_u \neq \gamma_o$, if the liability multipliers are constrained to be the same—say, γ—for both types of losses, there is no guarantee that the market outcome will be efficient even when γ is chosen optimally.

4. Noisy Diagnosis

Our main model has assumed that, when necessary, the expert can discover the nature of the consumer's problem by incurring the diagnosis cost. In this section we extend the model to consider the possibility of imperfect diagnosis. Specifically, in the event that the expert does not learn t upon seeing the consumer, he can privately observe a noisy signal $s \in \{s_m, s_M\}$ about t by incurring the private diagnosis cost k. The signal is correct with probability σ about the true type of the consumer, that is

$$\Pr(s_m \mid t = m) = \sigma = \Pr\{s_M \mid t = M\}, \tag{23a}$$

$$\Pr(s_m \mid t = M) = 1 - \sigma = \Pr\{s_M \mid t = m\}. \tag{23b}$$

We assume

$$\sigma > \frac{\max\{(1-\theta)(z_u - C), \theta(C + z_o)\}}{(1-\theta)(z_u - C) + \theta(C + z_o)} \equiv \underline{\sigma} \tag{24}$$

so that the signal is informative and there exist parameter values under which it is efficient for the expert to exert diagnosis effort.[12] We further assume $\theta > \frac{1}{2}$ so that the consumer's problem is more likely to be minor. Everything else remains the same as in the main model.

Note that the total surpluses from strategies (N, T_M) and (N, T_m) are not affected by the noisy signal. The total surplus from strategy E_T—exerting diagnosis effort and recommending T_t if signal s_t is received—is

$$W(E_T) = \theta\,[(1-\sigma)\,(-C - z_o)] + (1-\theta)\,[-\sigma C - (1-\sigma)\,z_u] - k \tag{25}$$

$$= \theta\sigma(z_o + C) - (1-\theta)(1-\sigma)(z_u - C) - C - \theta z_o - k. \tag{26}$$

[12]If $\sigma \leq \underline{\sigma}$, it would not be efficient for the expert to exert diagnosis effort. In that case an equal price margin on the two treatments would lead to the efficient outcome.

Exerting effort is efficient when $W(E_T) \geq \max\{W(N, T_M), W(N, T_m)\}$, which holds if

$$k \leq \min \left[\begin{array}{c} \theta\sigma(C + z_o) - (1-\theta)(1-\sigma)(z_u - C), \\ (1-\theta)\sigma(z_u - C) - \theta(1-\sigma)(C + z_o), \bar{k} \end{array} \right] \equiv k^{**}(z_o, z_u). \quad (27)$$

For $\sigma < 1$, $k^{**}(z_o, z_u) < k^*(z_o, z_u)$. Imperfect diagnosis reduces the critical value of diagnosis cost. Assumption (24) ensures $k^{**}(z_o, z_u) > 0$ so that if $k < k^{**}(z_o, z_u)$ it is efficient for the expert to acquire the signal.

Lemma 2 summarizes the first-best outcome when diagnosis is imperfect.

Lemma 2 *With noisy diagnosis, if the expert learns t upon seeing the consumer, it is efficient for him to choose T_t for $t = m, M$. Otherwise: (i) If $k > k^{**}(z_o, z_u)$ and $z_o \leq z_o^*$, it is efficient to choose (N, T_M); (ii) If $k > k^{**}(z_o, z_u)$ and $z_o \geq z_o^*$, it is efficient to choose (N, T_m); (iii) If $k \leq k^{**}(z_o, z_u)$, it is efficient to choose E_T and follow the signal (i.e., recommending T_t if signal s_t is received).*

Given a pair of prices $\Phi = (\Phi_M, \Phi_m)$, the expert's profit from strategies (N, T_M) and (N, T_m) are the same as in the main model, but the profit from E_T becomes:

$$\pi(E_T) = \theta[\sigma\Phi_m + (1-\sigma)(\Phi_M - \alpha_o D_o)] + (1-\theta)[\sigma\Phi_M + (1-\sigma)(\Phi_m - \alpha_u D_u)] - k.$$

The expert's optimal strategy is E_T if and only if $\pi(E_T) \geq \max\{\pi(N, T_M), \pi(N, T_m)\}$, or equivalently if and only if k is sufficiently small:

$$k \leq \min \left\{ \begin{array}{l} [\theta\sigma + (1-\theta)(1-\sigma)]\,(\Phi_m - \Phi_M) + \theta\sigma\alpha_o D_o - (1-\theta)(1-\sigma)\alpha_u D_u, \\ [\theta(1-\sigma) + (1-\theta)\sigma]\,(\Phi_M - \Phi_m) - \theta(1-\sigma)\alpha_o D_o + (1-\theta)\sigma\alpha_u D_u \end{array} \right\}$$
$$\equiv \tilde{k}(D, \Phi). \tag{28}$$

If the expert needs to incur k, it would be optimal for him to follow signal s_t *if and only if* the prices (Φ_M, Φ_m) satisfy

$$\Phi_M - (1-\sigma)\,\alpha_o D_o \;\; \geq \;\; \Phi_m - \sigma\alpha_u D_u, \tag{29a}$$
$$\Phi_m - (1-\sigma)\,\alpha_u D_u \;\; \geq \;\; \Phi_M - \sigma\alpha_o D_o. \tag{29b}$$

Note that if a pair of prices (Φ_M, Φ_m) satisfy (29), they also satisfy constraint (8) so that the expert reports truthfully if he learns the consumer's type t immediately. Let $\pi(N, T_M) - \pi(N, T_m) = \Delta$. Then using (9), we have

$$\Phi_M - \Phi_m = \Delta + \theta\alpha_o D_o - (1-\theta)\alpha_u D_u. \tag{30}$$

Constraint (29) is equivalent to

$$(1-\sigma-\theta)(\alpha_o D_o + \alpha_u D_u) \leq \Delta \leq (\sigma - \theta)(\alpha_o D_o + \alpha_u D_u). \tag{31}$$

Note that if $\sigma < \theta$, $\Delta < 0$ has to hold for (29) to be satisfied, that is, the expert has to receive more surplus from (N, T_m) than from (N, T_M). Proposition 3 below, the proof of which is relegated to the appendix, characterizes the optimal liability rules that implement the efficient outcome as described in Lemma 2.

Proposition 3 *(i) If $\sigma \geq \theta$, the following liability rule results in the efficient* *outcome in equilibrium:*

$$\tilde{D}_u = \frac{k^{**}(z_o, z_u)}{(1-\theta)(2\sigma-1)\alpha_u}, \qquad \tilde{D}_o = \frac{k^{**}(z_o, z_u)}{\theta(2\sigma-1)\alpha_o}. \tag{32}$$

(ii) If $\theta > \sigma > \frac{\theta - \sqrt{\theta-\theta^2}}{2\theta-1} \equiv \tilde{\sigma}$, the efficient outcome is achieved with liability rule

$$\bar{D}_o = \frac{k^{**}(z_o, z_u)}{2\alpha_o[(1-\theta)\sigma^2 - \theta(1-\sigma)^2]}, \qquad \bar{D}_u = \frac{k^{**}(z_o, z_u)}{2\alpha_u[(1-\theta)\sigma^2 - \theta(1-\sigma)^2]}. \tag{33}$$

(iii) If $\underline{\sigma} \leq \sigma \leq \tilde{\sigma}$, the efficient outcome can not be achieved in equilibrium.

Thus, the efficient outcome can be implemented if σ is sufficiently large ($\sigma > \tilde{\sigma}$). Because of constraint (31), the liability rules that implement efficiency differ when $\sigma \geq \theta$ or $\tilde{\sigma} < \sigma < \theta$. But if σ is below the threshold, $\tilde{\sigma}$, efficiency cannot be implemented.

Intuitively, when $\sigma \geq \theta > 1/2$, $\Delta = 0$ maximizes $\tilde{k}(D, \Phi)$ and is also a feature of the equilibrium price. The analysis is thus similar to that in the main model where the signal is perfect ($\sigma = 1$). As in the main model, the markups for the two treatments are equal in equilibrium under the efficient liability rule.

When $\sigma < \theta$, $\Delta < 0$ in order for the truthful reporting incentive (31) to hold. In this case, the equilibrium prices for a given liability rule (D_o, D_u) are

$$\bar{\Phi}_M = \theta\alpha_o D_o, \quad \bar{\Phi}_m = (1-\sigma)\alpha_u D_u + (\theta-\sigma)\alpha_o D_o. \tag{34}$$

At the efficient liability rule $(\bar{D}_o, \bar{D}_u)$, we notice that $\bar{\Phi}_M \neq \bar{\Phi}_m$. Thus, when the expert's diagnosis only leads to a noisy signal about the patient's problem, the equilibrium markups for the two treatments may not be equal at the efficient liability rule.

Finally, when $\sigma \leq \tilde{\sigma}$, $\sigma^2(1-\theta) - \theta(1-\sigma)^2 < 0$. Given a pair of prices that satisfy (31) and the upper bound of Δ in (31), the expert would exert diagnosis effort only if k is below

$$\tilde{k}(D, \Phi) < (\sigma^2(1-\theta) - \theta(1-\sigma)^2)(\alpha_o D_o + \alpha_u D_u) \leq 0. \tag{35}$$

Therefore, there is no liability rule that could induce the expert to report his information truthfully and also to incur any positive diagnosis cost. In other words, when the signal is not informative enough, even though it is still welfare-improving to acquire the signal, eliciting truthful reporting of information from the expert requires unbalanced markups ($\Delta < 0$) for the two treatments, which in turn squeezes out the expert's information acquisition incentive.

5. Conclusion

This paper has studied liability for expert services in a model of adverse selection and moral hazard. We have shown that a liability rule can be designed to motivate the expert to choose both the treatment type and the diagnosis effort efficiently. This efficient liability rule assesses penalty to the expert contingent on whether his "malpractice" involves overtreatment or undertreatment and the size of the consumer loss. The penalty may be punitive, in the sense it exceeds consumer's loss, and is higher when the probability of detection for the mistreatment is lower. We also find that the efficient outcome can be achieved with a well-designed liability rule even when the expert's diagnosis effort produces a noisy signal about the nature of the consumer's problem, but only when the signal is sufficiently informative.

A prominent example of credence goods is medical services provided by physicians. Our results offer insights on the regulation of physicians/hospitals' incentives through a well-designed liability rule and appropriate payment schemes. First, our efficient liability rule suggests that there should be a distinction between overtreatment and undertreatment in the enforcement of liability rules in credence good markets. Both types of mistreatments can cause harm to consumers. Although overtreatment has been largely ignored in the credence good literature, it has attracted much attention in recent years and, as a response, "fraud liability based on overtreatment" has emerged.[13] Our theory suggests that if there is a positive probability that an overtreatment can be verified, an outcome-contingent liability rule would improve market efficiency.

Second, policy and regulation should aim to achieve balanced prices—taking into account the liability cost—for different types of treatments. When the price margins for different types of treatments differ substantially, experts are not incentivized to recommend the most appropriate treatment.[14] Our analysis indicates that to combat this problem, in addition to possibly reducing the difference in price margins for different treatments, a well-designed liability rule can generate the same expected payoff to the expert—even if

[13] Overtreatment is claimed to be among the major reasons for the ever-increasing medicare expenses in the U.S.. The American College of Physicians estimates that $250 billion is wasted annually on all excessive testing and treatment in the U.S.. See Press Release, MedSolutions, MedSolutions responds to Choosing Wisely Campaign, Which Highlights Unnecessary Tests and Procedures (Apr. 5, 2012), available at http://www.reuters.com/article/2012/04/05/idUS162843+05-Apr-2012+BW20120405. A prominent case on overtreatment is the investigation undertaken by DOJ into the medical appropriateness of using implantable cardioverter defibrillators (ICDs).

[14] In 2011, John Dempsy Hospital was reported to administer chest "combination scans" at nearly ten times the national average. A related fact was that hospitals administering combination scans earn more in reimbursement from the medicare program than those that administer just one scan to a patient.(Buck, 2015.)

price margins differ—from different types of treatment. This can then deter the expert from recommending the wrong type of treatment.[15]

Third, the efficient liability rule require damage payments that may be well above the consumer's verified loss. Unlike other products for which consumer loss from product malfunction is relatively easy to determine, consumer loss from mistreatment for a credence good such as physician service has a much lower probability to be detected and verified, possibly requiring the assistance of other experts. In such situations, a high damage award may appear excessive ex post for a particular consumer given her verifiable loss, but is nevertheless needed ex ante to provide the efficient incentive for the expert.

Appendix

Proof of Proposition 3. Replacing $\Phi_M - \Phi_m$ in (28) by (30), we have

$$\tilde{k}(D, \Phi) = \min \left\{ \begin{array}{c} -(\theta\sigma + (1-\theta)(1-\sigma))\,\Delta + \theta(1-\theta)\,(2\sigma-1)\,(\alpha_o D_o + \alpha_u D_u)\,, \\ (\theta(1-\sigma) + (1-\theta)\sigma)\,\Delta + \theta(1-\theta)\,(2\sigma-1)\,(\alpha_o D_o + \alpha_u D_u) \end{array} \right\}$$

$$= \left\{ \begin{array}{lll} -(\theta\sigma + (1-\theta)(1-\sigma))\,\Delta + \theta(1-\theta)\,(2\sigma-1)\,(\alpha_o D_o + \alpha_u D_u) & \text{if} & \Delta > 0 \\ (\theta(1-\sigma) + (1-\theta)\sigma)\,\Delta + \theta(1-\theta)\,(2\sigma-1)\,(\alpha_o D_o + \alpha_u D_u) & \text{if} & \Delta < 0 \end{array} \right. .$$

[15]China has recently carried out a reform in health care system by increasing physicians' service/treatment fees while reducing the markups hospitals receive from selling medicines. This reform, aimed at curbing the overselling of expensive and unnecessary medicines, may fail to prevent overprovision of high-margin checkups and treatments if there is no corresponding reform in phyisician/hopital liability.

Note that $\tilde{k}(D, \Phi)$ is maximized if $\Delta = 0$. The consumer surplus from the three strategies, (N, T_M), (N, T_m) and E_T are respectively:

$$S(N, T_M) = \theta\left[-z_o - \Phi_M - C + \alpha_o D_o\right] + (1-\theta)\left[-\Phi_M - C\right], \tag{36}$$

$$S(N, T_m) = -\theta \Phi_m + (1-\theta)\left[-z_u - \Phi_m + \alpha_u D_u\right], \tag{37}$$

$$\begin{aligned} S\left(E_T\right) &= -\theta\left[\sigma \Phi_m + (1-\sigma)(\Phi_M + C - \alpha_o D_o)\right] \\ &\quad - (1-\theta)\left[\sigma\left(\Phi_M + C\right) + (1-\sigma)(\Phi_m - \alpha_u D_u)\right]. \end{aligned} \tag{38}$$

(i) $\sigma \geq \theta$. To satisfy (31), Δ can be either positive or negative.

If $\Delta > 0$, $\pi(N, T_M) > \pi(N, T_m)$, the expert would choose T_M if he is not initially informed about t and also does not incur k. Note that the consumer surplus

$$\begin{aligned} & S\left(E_T\right) - S(N, T_M) \\ = \; & \theta\left[\sigma\left(\Phi_M - \Phi_m + C - \alpha_o D_o\right) + z_o\right] + (1-\theta)(1-\sigma)\left[\left(\Phi_M + C\right) - \left(\Phi_m - \alpha_u D_u\right)\right] \\ = \; & \theta\left[\sigma\left(\Delta + C - (1-\theta)\left(\alpha_u D_u + \alpha_o D_o\right)\right) + z_o\right] \\ & + (1-\theta)(1-\sigma)\left[\Delta + C + \theta\left(\alpha_o D_o + \alpha_u D_u\right)\right] \\ = \; & \theta\sigma(\Delta + C) + (1-\theta)(1-\sigma)(\Delta + C) + \theta z_o - \theta(1-\theta)(2\sigma - 1)\left(\alpha_o D_o + \alpha_u D_u\right) \end{aligned}$$

is positive if the liabilities satisfy

$$\begin{aligned} & \alpha_u D_u + \alpha_o D_o \\ \leq \; & \frac{\min\left\{\left[\theta\sigma + (1-\theta)(1-\sigma)\right] C + \theta z_o, -\left[\theta(1-\sigma) + (1-\theta)\sigma\right] C + (1-\theta) z_u\right\}}{\theta(1-\theta)(2\sigma - 1)}. \end{aligned} \tag{39}$$

Thus, the consumer prefers E_T to (N, T_M). By reducing Φ_M (thus reducing Δ), $\tilde{k}(D, \Phi)$ will rise and the expert incurs the diagnosis cost more often and the consumer pays a lower price. Thus, if $\Delta > 0$, it is optimal for the consumer to reduce Δ by reducing Φ_M.

Similarly, one can show that if liabilities satisfy (39), $\Delta < 0$ is not optimal for the consumer either. As a result, an optimal price must satisfy $\Delta = 0$. Further note that a pair of prices such that $\pi(N, T_M) = \pi(N, T_m) = 0$ satisfy $\Delta = 0$ and at the same time are the lowest possible prices that guarantee (10), therefore, the consumer's optimal price must be

$$\hat{\Phi}_M = \theta\alpha_o D_o, \quad \hat{\Phi}_m = (1-\theta)\alpha_u D_u. \tag{40}$$

From (28), using the optimal prices (40), the expert incurs k if and only if $k \leq \tilde{k}\left(D, \hat{\Phi}\right) = \theta(1-\theta)(2\sigma-1)(\alpha_u D_u + \alpha_o D_o)$. Note that the efficient outcome is implemented in equilibrium if and only if $\tilde{k}(D, \hat{\Phi}) = k^{**}(z_o, z_u)$. It is straightforward to show that liability rule (32) satisfies (39) and indeed leads to $\tilde{k}(D, \hat{\Phi}) = k^{**}(z_o, z_u)$, thus achieving the efficient outcome.

(ii) $\theta > \sigma > \frac{\theta - \sqrt{\theta - \theta^2}}{2\theta - 1} \equiv \tilde{\sigma}$. Since $\sigma < \theta$, satisfying (31) requires $\Delta < 0$. From (28), we get

$$\tilde{k}(D, \Phi) = (\theta(1-\sigma) + (1-\theta)\sigma)\Delta + \theta(1-\theta)(2\sigma-1)(\alpha_o D_o + \alpha_u D_u).$$

Following the same procedure in part (i), one can show that if the liabilities satisfy

$$\alpha_o D_o + \alpha_u D_u \leq \frac{(1-\theta)z_u - (\theta(1-\sigma) + (1-\theta)\sigma)C}{\sigma^2(1-\theta) - \theta(1-\sigma)^2}, \tag{41}$$

$S(E_T) - S(N, T_m) > 0$ and the largest Δ is optimal for the consumer. Accounting for constraint (10), the equilibrium prices must be

$$\bar{\Phi}_M = \theta\alpha_o D_o, \quad \bar{\Phi}_m = (1-\sigma)\alpha_u D_u + (\theta - \sigma)\alpha_o D_o.$$

With the equilibrium prices $(\bar{\Phi}_M, \bar{\Phi}_m)$, the expert exerts diagnosis effort if and only if k does not exceed $\bar{k}\left(D,\bar{\Phi}\right) = \left[(1-\theta)\sigma^2 - \theta(1-\sigma)^2\right](\alpha_o D_o + \alpha_u D_u)$. As a result, liability rule (33) aligns the expert's incentive with that of a social planner and leads to $\bar{k}\left(D,\bar{\Phi}\right) = k^{**}(z_o, z_u)$. Since $(\bar{D}_o, \bar{D}_u)$ indeed satisfy (41), the efficient outcome is obtained in equilibrium.

(iii) $\sigma \leq \tilde{\sigma}$. This is equivalent to $\sigma^2(1-\theta) - \theta(1-\sigma)^2 \leq 0$. For any pair of prices that satisfy (31), the expert exerts diagnosis effort if k does not exceed

$$\begin{aligned}\tilde{k}(D,\Phi) &= (\theta(1-\sigma) + (1-\theta)\sigma)\,\Delta + \theta(1-\theta)\,(2\sigma-1)\,(\alpha_o D_o + \alpha_u D_u) \\ &\leq \left(\sigma^2(1-\theta) - \theta(1-\sigma)^2\right)(\alpha_o D_o + \alpha_u D_u) \leq 0\end{aligned}$$

where the second line obtains by replacing Δ with its upper bound $(\sigma - \theta)(\alpha_o D_o + \alpha_u D_u)$ in (31). Thus, there does not exist a pair of prices that ensures both honest reporting by the expert given his private information and efficient exertion of diagnosis effort. ■

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