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Abstract. We study the design of efficient liability in expert markets. An expert may misbehave in two ways: prescribing the "wrong" treatment for a consumer's problem, or failing to exert proper effort to diagnose the problem. We show that under a range of liabilities, the expert will choose the efficient treatment based on his information if the price margins for alternative treatments are close enough. Moreover, a well-designed liability rule motivates the expert to also exert diagnosis effort efficiently. The efficient liability is facilitated by certain restriction on equilibrium prices; unfettered competition between experts, while maximizing consumer surplus, may undermine efficiency.

Keywords: Credence goods, experts, liability, diagnosis effort, undertreatment, overtreatment

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). The problem is either minor or major, and there can be two potential treatments. The expert has private information about which treatment is appropriate for the consumer. Given his information advantage, the expert may recommend to and provide the consumer with the "wrong" treatment—a major treatment for a minor problem (*overtreatment*) or a minor treatment for a major problem (*undertreatment*)—if doing so increases his payoff. An extensive literature has analyzed this adverse selection problem in expert markets, where the good or service provided by the expert is sometimes called a credence good.[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 alternatives.

In many situations, the expert may need to exert costly effort to determine the consumer's problem and the type of treatment that is appropriate. For example, a patient with a bad cough and a fever may need only a minor treatment (home rest, possibly with some medication) or a major treatment that requires hospitalization, and the physician may need to exert diagnosis effort—such as spending more time with the patient, investigating related symptoms—to determine which treatment is appropriate.[2] To the extent that (some of) the diagnosis effort and its cost are the expert's private information, the expert may not exert it even when doing so is socially desirable. This moral hazard problem, which has been largely ignored in the literature on credence goods,[3] 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 find out the appropriate treatment for the consumer.

[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 the literature on credence goods in a unified framework.

[2] Alternatively, the expert service could be to repair a consumer's car, to fix a client's malfunctioning air-conditioning system, to provide advice on a client's legal problem, or to improve the security of a client's computer network. In all these situations, the expert may need to be provided with incentives both to incur (private) diagnosis cost and to report the consumer's problem honestly.

[3] Exceptions include Dulleck and Kerschbamer (2009) that investigates the incentives of experts to exert diagnostic effort and to report truthfully when the experts face competition from discounters who cannot perform diagnosis; and Bester and Dahm (2017) that analyzes the design of optimal contract when payment can be made contingent upon the consumer's report of her subjective evaluation of the treatment outcome in a combined model of adverse selection and moral hazard.

In this paper, we investigate the potential role of liability in disciplining the expert's behavior in a model with both adverse selection and moral hazard that captures the market environment as described above.[4] The consumer requires either a major or minor treatment depending on her (problem) type. Upon seeing the consumer, the expert either immediately learns—with his expertise—which treatment is appropriate, or can exert (additional) private effort to obtain this information. The type of treatment the expert provides is observed publicly but the outcome of treatment (thus whether the provided treatment is appropriate or not) is verifiable only with some probability. If the consumer suffers from a wrong treatment, there is some probability that the consumer can discover and verify the loss, in which case the expert is required to compensate the consumer according to some liability rule that is a function of the losses from mistreatments.[5]

We consider an environment where the prices for the two treatments are set to maximize consumer surplus, subject to a minimum-price condition that ensures each treatment to receive non-negative profit under the prior belief about the consume type.[6] 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 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 necessary 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.

[4]Bardey, et al (2018) analyze a market for experience goods that also combine both adverse selection and moral hazard. They study optimal regulation and to what extent competition can substitute for regulation to curb the distortions from these two problems. On the other hand, our paper studies liability design in markets that share features of a credence good.

[5]By contrast, the literature on credence goods assumes that consumers are unable to learn whether appropriate treatments have been provided, at least in the case of overtreatment which, by assumption, solves the consumer's problem (e.g., Emons,1997, 2001; Fong, 2005; Dulleck and Kerschbamer, 2006). Hence, the literature considers either infinite liability (for undertreatment) or zero liability (for overtreatment).

[6]What we have in mind are situations where either there are many potential experts competing in prices to serve the consumer or the consumer is able to make price offers; however, there is friction in competition among potential experts, or the consumer has limited power to commit to her price offers. Hence the expert retains the power to maintain certain minimum prices.

While there are many liability rules under which the expert will recommend honestly about the appropriate treatment given his private information, they generally do not provide the incentive for the expert to exert efficient diagnosis effort. We show that there exists a particular liability rule, together with the equilibrium prices it induces, that leads to efficient diagnosis effort and honest information reporting. The efficient liability rule specifies a damage payment for a verified loss—contingent on whether the loss is due to overtreatment or undertreatment and the probabilities that losses are verifiable—that equates the price margin for each treatment to the efficient critical value of the expert's diagnosis cost.[7] Then, the expert will incur the (extra) diagnosis cost if and only if the cost does not exceed the expected social benefit; and he will also choose the efficient treatment—the treatment that maximizes the expected total surplus—based on his information.

We further analyze our model without imposing the minimum-price constraint. We interpret this as there being unfettered competition between (potential) experts in the expert market, which maximizes consumer surplus. We show that if the expert can choose not to treat the consumer after seeing her (and also not to receive any payment), a situation that we term as "no obligation to serve", then it is possible that no liability rule can attain full efficiency. In this sense, increased competition in the expert market may reduce market efficiency. However, if the expert has the obligation to serve (i.e., he must treat the consumer after seeing her even when the realization of his diagnosis cost is very high), then there exists an efficient liability rule that restores full market efficiency.

Our finding that unfettered competition in expert markets can undermine efficiency may seem puzzling. If there exists a liability rule that induces the efficient outcome when competition is constrained by the minimum-price condition, why cannot an alternative liability rule ensure the efficient outcome when competition is unconstrained? The key to understanding this result is to recognize that when the consumer may be (partially) compensated through liability for her loss from a "wrong" treatment, she does not fully internalize the social cost of such a loss. The prices that maximize consumer surplus may thus be too low to provide efficient incentive for the expert to exert diagnosis effort. Consequently, the efficient role of liability is undermined

[7] Undertreatment and overtreatment may cause different amounts of harm to consumers, and overtreatment is generally believed to be more difficult to verify than undertreatment.

without the minimum-price constraint. Our analysis will illuminate such subtlety in the optimal design of liability.

The economic analysis of liability goes back to the seminal contributions by Brown (1973) and Shavell (1980). In markets where consumers can detect and verify a product's failure, the literature has studied how product liability rules affect a producer's incentives to improve product safety ex ante and to provide ex post remedy for an unsafe product (e.g., Daughety and Reinganum, 1995, 2008; Spier, 2011; Hua, 2011; Chen and Hua, 2012). See also Shavel (2007) for a survey on the analysis of liabilities for accidents. In credence goods markets where consumers are assumed to rely on experts to determine which treatment is appropriate, not much attention has been devoted to the role of liability in motivating the experts' effort and honesty, presumably because of the view that if consumers cannot tell whether or not a treatment is appropriate, liability would not be effective as an incentive mechanism.[8] Our departure is to recognize that while a consumer may lack the expertise to know the right treatment, with some probability she can learn and verify her loss from a wrong treatment, possibly from the expertise of other experts, as for instance in the case of medical malpractice.[9]

While our model applies to markets with expert services in general, perhaps its most prominent application is the health care market where physicians' incentives are regulated by medical malpractice liabilities (e.g., Danzon, 1991).[10] Studies suggest that 4 to 18 percent of patients seeking care in hospitals in the U.S. are victims of medical malpractice, which could cost between \$17-29 billion per year (e.g., Arlen, 2013). Liability for medical malpractice has emerged to discipline physicians and protect patients, but its performance has been controversial, and studies on its optimal design are scarce.[11] Our analysis sheds light in this regard. In particu-

[8] There have been studies under specific settings, as, for instance, Fong and Liu (2018) who considers how liability may affect the expert's incentive to maintain reputation in a model of adverse selection. Also related is Fong, Liu, and Wright (2014), which emphasizes the importance of verifiability.

[9] Our model can be considered as one of credence goods, although it differs from what is usually assumed for "pure" credence goods. The product in our model also differs from an experience good, the quality of which is fully revealed after consumption. Our assumption that the quality can be learned ex post only with some probability seems to better reflect reality in expert markets.

[10] There is abundant evidence showing that physicians respond to financial incentives in treatment choices. Gruber, Kim and Mayzlin (1999) finds that cesarean deliveries are more common if they are highly reimbursed relative to normal deliveries. Dickstein (2016) finds that capitated physicians tend to choose drugs that require fewer follow-up visits when treating depression. Using a large set of private health insurance claims, Coey (2015) finds that physicians' treatment choices in heart attack management respond to the payments they receive, and the response is quite large.

[11] As two important exceptions, Simon (1982) compares the performance of negligence rule with strict liability in the health care market, and points out the need for strict liability to motivate physicians to exert proper care

lar, our results suggest that malpractice liability is essential for motivating physicians to exert proper diagnosis efforts. The efficient liability level depends not only on the magnitude of the loss, but also on whether there is overtreatment or undertreatment, because their probabilities of detection often differ. Also, the efficient liability is sometimes punitive, (much) exceeding the patient's loss from a malpractice incident. Finally, it may not be efficient to give all the bargaining power to the consumer—or the health insurance company on her behalf—in setting prices for the services: without the minimum-price constraint that ensures non-negative profit for each treatment under prior belief, an efficient liability rule may fail to exist.

In the rest of the paper, we describe our model in section 2. Section 3 conducts the analysis under the assumption of a minimum-price constraint and presents our main results. In section 4, we analyze our model without assuming the minimum-price constraint. Section 5 concludes. Appendix A contains proofs for Propositions 1 and 3. Appendix B extends our analysis to a setting where diagnosis effort generates only a noisy signal about the consumer's problem and demonstrates that, under the minimum-price constraint, an efficient liability rule continues to exist if the signal is sufficiently informative.

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, which is appropriate if the consumer's problem is respectively m or M. If the problem is not treated, the consumer suffers a loss x_t for $t \in \{M, m\}$, with her expected loss without treatment being

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

to avoid inadvertent events; Arlen and MacLeod (2005) analyzes optimal liability in a model where the physician invests in expertise and the concern is inadequate treatment (but not overtreatment). The key conflict in both papers is a moral hazard problem. By contrast, in our model there are both moral hazard and adverse selection.

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 her 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 problem type m is treated with T_M, in which case the harm to the consumer is $z_o > 0$.[12] We further assume that the consumer is able to verify her loss z_u with probability $\alpha_u \in (0,1]$ when undertreatment has occurred, and to verify her loss z_o with probability $\alpha_o \in (0,1]$ when overtreatment has occurred.[13]

Note that the way we define consumer's utility differs from that in the credence goods literature, where the harm from overtreatment is usually normalized to zero, and 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 explicitly account for the increasing concern over the harm from overtreatment in practice (e.g., Brownlee, 2008; Buck, 2013, 2015).[14]

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

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

[13] It is difficult but not impossible to verify overtreatment in practice. In health care markets, overtreatment cases may center on the medical necessity of a procedure. For example, Dignity Health pays $37 million in False Claims Action, entering a settlement for improper and medically unnecessary hospital admissions. (Modern Healthcare, Oct. 30, 2014)

[14] Buck (2015) reported that John Dempsey Hospital was discovered in 2011 to administer chest combination CT scans at nearly 10 times the national average while health experts noted that combination scans do not provide more valuable information in comparison to a single CT scan in most of those situations. Excess combination scans subject patients to clearly identifiable harm: exposing them to large doses of radiation which increases the risk of developing cancer at later stage.

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.[15] 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, the expert learns the realization of t, while if $e = N$ (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, and we assume

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

so that (i) applying a major treatment without knowing whether $t = m$ or M is more efficient than leaving the problem untreated, and (ii) without knowing whether $t = m$ or M, there exist parameter values under which T_M is more efficient than T_m. The type of treatment provided to the consumer—e.g., whether a certain procedure is carried out—is assumed to be publicly observed. Thus, if the expert recommends treatment T_M, cost C must be incurred to implement the treatment.

The expert may be liable for a bad outcome that is a result of maltreatment. The liability rule specifies damage payments $D \equiv (D_o, D_u)$, so that the expert is required to pay $D_u > 0$ if it is verified that the consumer has received undertreatment with loss z_u, and he is required to pay $D_o > 0$ if it is verified that the consumer has received overtreatment with loss z_o.[16]

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

1. The consumer sets prices (P_M, P_m), possibly subject to certain constraint. [Equivalently,

[15] This effort is beyond the observable normal effort associated with seeing the consumer. The extra cost k may include the additional time the expert spends with the consumer, the effort to gather additional information or to learn new developments in treatment technology.

[16] In the existing literature on credence goods, the assumption of "liability" refers to the requirement that the expert fixes the consumer's problem, which is equivalent 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 levels of liabilities on the expert's behavior and the efficient liability rule.

(at least two) potential experts compete in prices, possibly under some market friction, to provide each treatment and one expert is chosen by the consumer.][17]

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 private diagnosis cost k. The expert then chooses whether to exert diagnosis effort (if it is needed) 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 D.

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 characterize the liability rule that implements the efficient outcome.

3.1 Efficient Benchmark

Suppose all information is public and the expert can be required to act efficiently in all possible situations. If the expert learns t upon seeing the consumer, it is clearly efficient for him to choose T_t for $t = m, M$. So we focus on the case where the expert needs to incur k in order to learn t. The total surplus of the expert and the consumer, from strategy (N, T_M) (implementing T_M without incurring diagnosis cost k) or from strategy (N, T_m) (implementing T_m without

[17] Arlen and MacLeod (2005) analyze a setting in which the patients are price setters while the physician market is fully competitive.

incurring cost k), is respectively

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

Following action E, the efficient choice for the expert is T_t for $t = m, M$. This strategy, denoted as E_T, leads to total surplus

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

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

$$z_o \leq \frac{z_u(1-\theta) - C}{\theta} \equiv z_o^* \qquad \text{or} \qquad z_u \geq \frac{\theta z_o + C}{1-\theta} \equiv z_u^*. \tag{6}$$

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

$$k \leq \min\left\{\theta(C + z_o),\ \ (1-\theta)(z_u - C),\ \bar{k}\right\} \equiv k^*(z_o, z_u), \tag{7}$$

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_t for $t = m, M$. Otherwise, it is efficient to choose (i) (N, T_M) if $k > k^*(z_o, z_u)$ and $z_o \leq z_o^*$; (ii) (N, T_m) if $k > k^*(z_o, z_u)$ and $z_o > z_o^*$; (iii) E_T if $k \leq k^*(z_o, z_u)$.*

Thus, when additional diagnosis effort is required to learn t, 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 choose 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

$$P_M = C + \Phi_M, \qquad P_m = \Phi_m, \tag{8}$$

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. 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_t for $t = m, M$ *if and only if*

$$\Phi_M \geq \Phi_m - \alpha_u D_u, \qquad \Phi_m \geq \Phi_M - \alpha_o D_o. \tag{9}$$

Our analysis will proceed under the presumption that (9) 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 (9) is indeed optimal for the consumer.[18]

Notice that for (9) to hold, $\Phi_M = \Phi_m$ if $D_u = D_o = 0$. That is, in order for the expert to recommend the appropriate treatment given his information, equal price margins from different treatments are required when no liability can be imposed on the expert (e.g., Dulleck and Kerschbamer, 2006). When there are liabilities—as we allow in this paper—$\Phi_M = \Phi_m$ is sufficient

[18] For our purpose to find the efficient liability, it is without loss of generality to devote out attention to situations where (9) is satisfied. If (9) is violated, the expert will have the perverse incentive to choose the "wrong" treatment even when he knows t, which cannot be efficient.

for (9) but no longer necessary: as long as the price 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 (9).

Given (9), under which the expert will choose T_t for $t \in \{m, M\}$ 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_t for $t = m, M$. For a given $D \equiv (D_u, D_o)$ and k, the expert's profits under each of these strategies are, respectively:

$$\pi(N, T_M) = \Phi_M - \theta\alpha_o D_o, \qquad \pi(N, T_m) = \Phi_m - (1-\theta)\alpha_u D_u, \tag{10}$$

$$\pi(E_T) = \theta\Phi_m + (1-\theta)\Phi_M - k, \tag{11}$$

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.

Our analysis in this section will impose the following minimum-price constraint:

$$\pi(N, T_M) \geq 0, \qquad \pi(N, T_m) \geq 0. \tag{12}$$

When (12) is satisfied, Φ_M and Φ_m are high enough so that the expert, whose outside option is zero profit, will receive non-negative expected profit from providing each treatment under his prior about t. This minimum price constraint may arise when both the expert and the consumer have some bargaining power: the expert can insist on charging prices that would ensure non-negative profit for offering each treatment under the prior belief, whereas the consumer can offer prices subject to this constraint. Notice that under (12), the expert will receive strictly positive profit when he is informed of t, and hence also strictly positive expected profit from market participation. We shall say that there is unfettered competition between potential experts when

(12) is not imposed, in which case prices will be set to maximize consumer surplus without any constraint.[19]

Upon seeing the consumer, the expert either learns the realization of t and chooses T_t, or, without learning t, he learns the realizations of his private diagnosis cost k and chooses his action from $\{(N,T_M),(N,T_m),E_T\}$.[20] Thus, following a pair of prices $\Phi \equiv (\Phi_M,\Phi_m)$, the expert's optimal strategy when he does not initially learn t is E_T if and only if $\pi(E_T) \geq \max\{\pi(N,T_M),\pi(N,T_m)\}$, or if k is sufficiently small:

$$k \leq \min\{\theta\left(\Phi_m - \Phi_M + \alpha_o D_o\right),\ (1-\theta)\left(\Phi_M - \Phi_m + \alpha_u D_u\right)\} \equiv \hat{k}(D,\Phi). \tag{13}$$

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

$$\pi(N,T_M) - \pi(N,T_m) = \Phi_M - \theta\alpha_o D_o - [\Phi_m - (1-\theta)\alpha_u D_u] > 0. \tag{14}$$

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

$$S(N,T_M) = \theta\left[-z_o - \Phi_M - C + \alpha_o D_o\right] + (1-\theta)\left[0 - \Phi_M - C\right], \tag{15}$$

$$S(N,T_m) = \theta\left[-\Phi_m\right] + (1-\theta)\left[-z_u + \alpha_u D_u - \Phi_m\right], \tag{16}$$

$$S\left(E_T\right) = -\theta\Phi_m - (1-\theta)\left(\Phi_M + C\right). \tag{17}$$

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

$$S\left(E_T\right) - S(N,T_M) = \theta\left[\Phi_M - \Phi_m + C + z_o - \alpha_o D_o\right], \tag{18}$$

$$S\left(E_T\right) - S(N,T_m) = (1-\theta)\left(\Phi_m - \Phi_M - C + z_u - \alpha_u D_u\right). \tag{19}$$

We show below in the proof of Proposition 1 that the consumer's optimal prices satisfy

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

[19]In Section 4, we examine the equilibrium outcome and optimal liability without (12), where we show that there may exist no liability rule that ensures full efficiency.

[20]Condition (12) is important here, because if $\pi(N,T_M) < 0$ or $\pi(N,T_m) < 0$ (as we will allow in Section 4), the expert may choose to forgo the consumer's payment without treating her, if he finds that a high enough k is required to diagonose the consumer's problem. Condition (12) ensures that the expert will always be willing to serve the consumer.

Then, it follows from (18) and (19) that the consumer is willing to implement E_T with a positive probability—when the expert does not initially learn t and k is not too high— only if the total expected liability payments are not too high:

$$\alpha_u D_u + \alpha_o D_o \leq \min\left\{\frac{C + z_o}{1-\theta}, \ \frac{z_u - C}{\theta}\right\}. \tag{21}$$

Proposition 1 *Suppose that (12) holds. In equilibrium, for any given $D = (D_u, D_o)$ satisfying (21), $\Phi = \hat{\Phi} = \left(\hat{\Phi}_M, \hat{\Phi}_m\right)$, where:*

$$\hat{\Phi}_M = \theta\alpha_o D_o, \quad \text{and} \quad \hat{\Phi}_m = (1-\theta)\alpha_u D_u. \tag{22}$$

If the expert learns t upon seeing the consumer, he will choose T_t. Otherwise, he will choose E_T when $k \leq \hat{k}\left(D, \hat{\Phi}\right) = \theta(1-\theta)\left(\alpha_u D_u + \alpha_o D_o\right)$, whereas he will choose T_M if $z_o < z_o^*$ and T_m if $z_o > z_o^*$ when $k > \hat{k}$.

Proof. See Appendix A. ■

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 price offers under the constraint that the expert is able to earn a non-negative profit in each treatment under the prior belief. As we show in section 4, without this constraint, the consumer may find it optimal to offer prices that violate (12).

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. If margins differ so much that they violate (9), then the expert may choose the wrong treatment when he has the information. Moreover, if liability D_u or D_o is high enough so that (21) 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 situation will not arise if the liability satisfies (21), which also induces price margins for the two treatments to be close enough to satisfy (9).

Third, for arbitrary liabilities (D_o and D_u) satisfying (21), while the equilibrium prices will induce the expert to choose the efficient treatment given his information, $\hat{k}(D, \hat{\Phi})$ will generally not equal to $k^*(z_o, z_u)$. Therefore the equilibrium generally does not lead to the efficient diagnosis effort choice.

3.3 Efficient Liability

Recall that under the equilibrium prices given in (22), inefficiency arises only when $\hat{k}\left(D, \hat{\Phi}\right) \neq k^*(z_o, z_u)$, where

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

with $k^*(z_o, z_u) = \min\left\{\theta(C + z_o),\ \bar{k}\right\}$ if $z \leq z_o^*$ and $k^*(z_o, z_u) = \min\left\{(1-\theta)(z_u - C),\ \bar{k}\right\}$ if $z > z_o^*$. If the liability rule can ensure $\hat{k}\left(D, \hat{\Phi}\right) = k^*(z_o, z_u)$, the expert will choose the diagnosis effort efficiently and the benchmark outcome as described in Lemma 1 is achieved. 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 *Suppose that (12) holds. Then, the following liability rule results in the efficient outcome in equilibrium:*

$$D_u^* = \frac{k^*(z_o, z_u)}{(1-\theta)\alpha_u}, \qquad D_o^* = \frac{k^*(z_o, z_u)}{\theta\alpha_o}. \tag{23}$$

Proof. The liability rule under (23) satisfies (21), and hence in equilibrium the price margins satisfy (22), 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 $z_o > z_o^*$. Moreover, 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 rule that implements the efficient outcome, the equilibrium price margin for each treatment is equal to the efficient critical k, $k^*(z_o, z_u)$. Thus, while there exist a range of liabilities that would induce the equilibrium markups given in (22) for the two treatments and these markups generally differ, they are the same under the efficient liability. Intuitively, the equilibrium price margin is equal to the expert's expected liability cost for each treatment when he chooses the treatment without knowing t. By selecting D^* that equates this liability cost to the efficient k^*, the efficient liability incentivizes the expert to fully internalize the social benefit from choosing the efficient diagnosis effort.

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.

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

$$\gamma_u = \frac{k^*(z_o, z_u)}{(1-\theta)\alpha_u z_u}, \qquad \gamma_o = \frac{k^*(z_o, z_u)}{\theta\alpha_o z_o}. \tag{24}$$

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 efficient 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, the market outcome will generally be inefficient.

4. Relaxing the Minimum Price Constraint

We now analyze the model without imposing minimum price constraint (12). To focus on the more interesting cases, we assume[21]

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

From Proposition 2, efficiency can be achieved when $\Phi_M \geq \theta\alpha_o D_o$ and $\Phi_m \geq (1-\theta)\alpha_u D_u$. Hence, in this section we shall consider situations where at least one of these two inequalities may be reversed in equilibrium (with $D_o > 0$ or/and $D_u > 0$).

If $\Phi_M < \theta\alpha_o D_o$ or $\Phi_m < (1-\theta)\alpha_u D_u$, the expert may earn negative expected profit when choosing T_M or T_m based on prior belief about t, in which case the expert may choose not to treat the consumer if the diagnosis cost (k) is high. Thus, when (12) is not required, the market outcome may depend on whether or not the expert has the obligation to serve after seeing the consumer. Below, we examine in turn the two cases where, after seeing the consumer, the expert has no obligation to serve or where he is obligated to serve. We will characterize the optimal—i.e., welfare-maximizing—liability and investigate whether/when it achieves the efficient outcome. We shall continue to assume that the liability and prices satisfy (9) and (21), which will be shown to hold in equilibrium.

4.1 No Obligation to Serve

We first consider the case where the expert can choose not to serve the consumer if, after seeing the consumer, he finds that his expected profit from service is negative.

Suppose that $z_o < z_o^*$, so that $k^* = \theta(C + z_o)$ and $W(N, T_M) > W(N, T_m)$.[22] The expert exerts effort in information acquisition if and only if

$$\pi(E_T) \geq \max\{0, \pi(N, T_M), \pi(N, T_m)\}.$$

Then, it can be easily verified that the relevant equilibrium prices involve either (i) $\Phi_M = \theta\alpha_o D_o$

[21]If $k^* = \bar{k}$, it would be efficient for the expert to choose $e = E$ for any realization of k when additional effort is required to diagnose the consumer's problem. Then, any wrong treatment is a sign of inefficient diagnosis effort, and the efficient outcome can be achieved with sufficiently large (D_o, D_u).

[22]The analysis for the case where $z_o > z_o^*$ is analogous and is briefly discussed later.

and $\Phi_m \leq (1-\theta)\alpha_u D_u$, with the expert selecting T_M if he chooses between T_M and T_m based on prior belief about t; or (ii) $\Phi_M < \theta\alpha_o D_o$ and $\Phi_m < (1-\theta)\alpha_u D_u$.[23] Under case (i) and with (21), from (15) and (17):

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

and under case (ii), the expert provides a treatment only if he knows t (either initially or by incurring k) and never selects T_M or T_m based on prior belief about t. Under each of the two cases, the expert exerts diagnosis effort if and only if k does not exceed $\hat{k} = \theta\Phi_m + (1-\theta)\Phi_M$.

Therefore, with $0 \leq \Phi_m \leq (1-\theta)\alpha_u D_u$, the consumer's surplus under $z_o < z_o^*$ and no obligation to serve is:

$$S^a(\Phi_M,\Phi_m) = \begin{cases} \beta S(E_T) + (1-\beta)S(N,T_M) + (1-\beta)F\left(\hat{k}\right)\left[S(E_T) - S(N,T_M)\right] & if \quad \Phi_M = \theta\alpha_o D_o \\ \beta S(E_T) + (1-\beta)(-x) + (1-\beta)F\left(\hat{k}\right)\left[S(E_T) - (-x)\right] & if \quad \Phi_M < \theta\alpha_o D_o \end{cases},$$

where

$$\hat{k} = \theta\Phi_m + (1-\theta)\Phi_M \leq \theta(1-\theta)\alpha_u D_u + (1-\theta)\theta\alpha_o D_o \leq \theta(C + z_o).$$

Notice that $S^a(\Phi_M,\Phi_m)$ is continuous in Φ_m and upper semi-continuous in Φ_M, having the only potential discontinuous point at $\Phi_M = \theta\alpha_o D_o$. Thus there exists some

$$(\Phi_M^a, \Phi_m^a) = \arg\max_{\substack{\Phi_M \in [0,\theta\alpha_o D_o], \\ \Phi_m \in [0,(1-\theta)\alpha_u D_u]}} S^a(\Phi_M,\Phi_m). \quad (25)$$

Proposition 3 *Suppose $z_o < z_o^*$. Then, for given (D_o, D_u) satisfying (21), $(\Phi_M,\Phi_m) = (\Phi_M^a,\Phi_m^a)$ in equilibrium. Moreover, given other parameter values, there exist $x^a > 0$ and $\beta^a < 1$ such that: (i) if $x > x^a$, then $D_o = \frac{C+z_o}{(1-\theta)\alpha_o}$ and $D_u = 0$ induce the efficient outcome, with $\Phi_M^a = \frac{\theta(C+z_o)}{1-\theta}$ and $\Phi_m^a = 0$; (ii) if $\beta > \beta^a$, there exists no (D_o, D_u) that can lead to full efficiency.*

Proof. See Appendix A. ■

[23] The third possiblity is $\Phi_M < \theta\alpha_o D_o$ and $\Phi_m = (1-\theta)\alpha_u D_u$, in which the expert would choose T_m if he treats the consumer based on prior belief. Under (21) and $z_o < z_o^*$, one can verify that $S(N,T_M) > S(N,T_m)$, so that the consumer will prefer $\Phi_M = \theta\alpha_o D_o$ and $\Phi_m < (1-\theta)\alpha_u D_u$ to $\Phi_M < \theta\alpha_o D_o$ and $\Phi_m \geq (1-\theta)\alpha_u D_u$.

In part (i) of Proposition 3, when x is large enough, the consumer is always better off with treatment T_M based on prior belief than without treatment. Hence the consumer will offer $\Phi_M = \theta\alpha_o D_o$ so that the expert will choose (N, T_M) in case he does not learn t initially and k turns out to be too high, and she will offer $\Phi_m = 0$ to minimize the expert's rent in case he learns t initially or by incurring k. If $D_o = \frac{C+z_o}{(1-\theta)\alpha_o}$ and $D_u = 0$, then

$$\hat{k} = \theta\Phi_m^a + (1-\theta)\,\Phi_M^a = (1-\theta)\,\frac{\theta\,(C+z_o)}{1-\theta} = \theta\,(C+z_o) = k^*,$$

so that the expert will incur diagnosis effort efficiently, and he will also report information truthfully since (21) is satisfied.

To see the intuition for part (ii) of Proposition 3, notice that when the consumer can be (partially) compensated for the loss associated with an inappropriate treatment, she does not bear the full social cost of the loss. Hence, in order to reduce the expert's information rent, the consumer may want to lower the prices below the level that would induce the efficient effort and satisfy the minimum-price constraint (12), and she will indeed do so when β is high so that the expert will choose the appropriate treatment sufficiently often even without incurring k. Hence, when β is sufficiently high, an efficient liability—one that will ensure $\hat{k} = k^*$—fails to exist.

Therefore, if competition between potential experts drives the price margins below $\hat{\Phi}$, equilibrium need no longer be efficient, even when the liability rule is chosen optimally. The lower price increases consumer surplus—the consumer can always offer the prices satisfying (12) but chooses to offer lower prices—albeit at the expense of total welfare because the gain to the consumer is less than the loss to the expert. This highlights the subtlety in the design of an efficient liability: while liability is necessary to provide incentives for the expert to exert effort, it also creates a divergence between the social and private costs of a loss to the consumer. Consequently, if there is perfect competition in the expert market without any restriction on prices, inefficiency may arise even under an optimally designed liability rule.

When $z_o > z_o^*$, a similar analysis can establish that there exist some $x^b > 0$ and $\beta^b < 1$ such that if $x > x^b$, then $D_o = 0$ and $D_u = \frac{z_u - C}{\theta\alpha_u}$ induce the efficient outcome, with $\Phi_M^b = 0$ and $\Phi_m^b = \frac{(1-\theta)(z_u - C)}{\theta}$; whereas if $\beta > \beta^b$, no (D_o, D_u) can lead to full efficiency.

4.2 With Obligation to Serve

Now suppose that the expert is obligated to serve after seeing the consumer, i.e., after seeing the consumer, the expert cannot choose not to provide treatment by forgoing the payment. As before, we assume that (D_o, D_u) and prices satisfy (21) and (9).

Given (D_o, D_u), the consumer chooses (Φ_m, Φ_M) to maximize her expected surplus, subject to the constraint that the expert receives non-negative expected profit by agreeing to see the consumer. The expert will incur k if and only if

$$\pi(E_T) = \theta\Phi_m + (1-\theta)\Phi_M - k \geq \max\{\pi(N, T_M), \pi(N, T_m)\}, \quad \text{or equivalently}$$
$$k \leq \hat{k}(D, \Phi) = \min\{\theta(\Phi_m - \Phi_M + \alpha_o D_o), (1-\theta)(\Phi_M - \Phi_m + \alpha_u D_u)\}.$$

The expert is willing to accept (Φ_m, Φ_M) if:

$$\Pi(D, \Phi) = \left(\beta + (1-\beta)F(\hat{k})\right)(\theta\Phi_m + (1-\theta)\Phi_M) - (1-\beta)\int_0^{\hat{k}} t dF(t)$$
$$+ (1-\beta)(1-F(\hat{k}))\max\{\Phi_M - \theta\alpha_o D_o, \Phi_m - (1-\theta)\alpha_u D_u\} \geq 0.$$

Define

$$D_o^* = \frac{k^*}{\theta\alpha_o}, \qquad D_u^* = \frac{k^*}{(1-\theta)\,\alpha_u}; \tag{26}$$

$$\Phi_M^* = (1-\beta)\left[k^* - \int_0^{k^*} F(t)dt\right] = \Phi_m^*. \tag{27}$$

Notice that (D_o^*, D_u^*) satisfy (21).

Proposition 4 *Suppose that the expert is obligated to treat the consumer after seeing her. Then, liability (26), under which the equilibrium prices satisfy (27), leads to full efficiency, where the expert will agree to serve, exert diagnosis effort if and only if $k \leq k^*$, and choose T_t whenever $t \in \{m, M\}$ is known to him.*

Proof. First, from the proof of Proposition 1, the equilibrium prices $(\Phi_M^*,\ \Phi_m^*)$ satisfy

$$\Phi_M^* - \theta\alpha_o D_o = \Phi_m^* - (1-\theta)\,\alpha_u D_u.$$

Thus, under (26), the expert will choose k efficiently:

$$\hat{k}(\Phi_m^*, \Phi_M^*) = \min\{\theta\left(\Phi_m^* - \Phi_M^* + \alpha_o D_o\right), (1-\theta)\left(\Phi_M^* - \Phi_m^* + \alpha_u D_u\right)\}$$
$$= \theta(1-\theta)(\alpha_o D_o^* + \alpha_u D_u^*) = k^*.$$

Next, with

$$\pi(N, T_M) = \Phi_M^* - \theta\alpha_o D_o^* = \Phi_m^* - (1-\theta)\alpha_u D_u^* = \pi(N, T_m),$$

if $k > k^*$, the expert will choose (N, T_M) when $z_o \leq z_o^*$ and (N, T_m) when $z_o > z_o^*$. Moreover:

$$\begin{aligned}\Pi(D^*, \Phi^*) &= \left[\beta + (1-\beta)F(k^*)\right]\left\{\Phi_M^* + \theta\left[(1-\theta)\alpha_u D_u^* - \theta\alpha_o D_o^*\right]\right\} \\ &\quad + (1-\beta)\left[1 - F(k^*)\right]\left(\Phi_M^* - \theta\alpha_o D_o^*\right) - (1-\beta)\int_0^{k^*} tf(t)dt \\ &= \Phi_M^* - \theta\alpha_o D_o^* - (1-\beta)\int_0^{k^*} tf(t)dt + \left[\beta + (1-\beta)F(k^*)\right]k^* \\ &= \Phi_M^* - \theta\alpha_o D_o^* + \beta k^* + (1-\beta)\int_0^{k^*} F(t)dt = 0\end{aligned}$$

if Φ_M^* and Φ_m^* satisfy

$$\Phi_M^* = \theta\alpha_o D_o^* - \beta k^* - (1-\beta)\int_0^{k^*} F(t)dt,$$
$$\Phi_m^* = (1-\theta)\alpha_u D_u^* - \beta k^* - (1-\beta)\int_0^{k^*} F(t)dt,$$

which simplify to (27). Note that these prices are optimal for the consumer subject to $\Pi(D, \Phi) \geq 0$,

$$\hat{k} = k^* = (1-\theta)\Phi_M^* + \theta\Phi_m^* = (1-\beta)\int_0^{k^*}\left[1 - F(t)\right]dt \geq 0,$$

and (Φ_M^*, Φ_m^*) indeed satisfy (9). They are thus equilibrium prices. ■

Therefore, if the expert is obligated to serve after seeing the consumer, then there exists an efficient liability that induces full efficiency under market equilibrium, even without imposing the minimum price condition (12). In reality, the obligation to serve may be difficult to implement. After an initial consultation, it would seem reasonable that the expert, without taking any payment from the consumer, will have the right not to provide treatment. A dentist, for example, may simply refer a patient to a “specialist” after seeing her.

5. Conclusion

This paper has studied the design of efficient liability in expert markets. Our analysis shows that a well designed liability rule, in combination with the equilibrium prices it induces, 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 the appropriate treatment. This efficient liability rule imposes penalty on 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 increased competition in the expert market, in the sense that it removes the minimum-price constraint, may reduce efficiency. The existence of an efficient liability also depends on whether the expert is obligated to serve when the price constraint is not imposed, as well as on the quality of signals generated from the expert’s diagnosis effort.

We have studied a stylized model. There are other factors that can potentially impact the performance of expert markets. For example, in the context of repeat purchases, reputation concerns can incentivize experts to exert efforts and behave honestly in serving consumers. But reputation can be fragile, and a well-designed liability rule can achieve efficiency even when reputation does not. It is also possible that the expert and the consumer will rely on private contracts, instead of legal liability, for damage payments in the case of a consumer loss; but private contracting can have high transaction costs and contract enforcement may still rely on the legal system. On the other hand, the use of liability as an incentive device may involve additional legal and transaction costs as well, which we have not accounted for in our analysis. Moreover, the beneficial effect of liability on market efficiency relies on its proper design and a well-functioning legal process, which may not always be the case in practice.

The difficulties in providing proper incentives to experts (such as physicians and dentists) are well known. By showing how an efficient liability can be designed in a model of adverse selection and moral hazard, this paper offers new insights on improving the performance of expert markets.

6. Appendices

Appendix A: Proofs for Propositions 1 and 3.

Proof of Proposition 1. We first show that the consumer's optimal prices indeed satisfy (20). Let $\pi(N,T_M) - \pi(N,T_m) = \Delta$. Then from (14),

$$\Phi_M - \Phi_m = \Delta + \theta\alpha_o D_o - (1-\theta)\alpha_u D_u. \tag{28}$$

From (13), 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

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

We show that (20) holds, or $\Delta = 0$, by demonstrating that the consumer can benefit from deviating to different prices if $\Delta \neq 0$. When the expert does not learn t upon seeing the consumer, there are two cases to consider:

Case 1: $\Delta > 0$. Then $\pi(N,T_M) > \pi(N,T_m)$ and the expert would choose T_M if he is not initially informed about t and also does not incur k. From (18) and (28):

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

Thus the consumer prefers E_T to (N,T_M). By reducing Φ_M slightly, Δ becomes smaller and $\hat{k}(D,\Phi)$ will rise—so that the expert incurs k more often while (9) 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.

Case 2: $\Delta < 0$. 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 (9) is satisfied. In this case, if $\Delta \neq 0$, consumer surplus can be increased by reducing either Φ_M or Φ_m. Thus (20) holds in equilibrium.

Next, under (12), the lowest prices that satisfy (20) are such that $\pi(N, T_M) = 0$ and $\pi(N, T_m) = 0$. Hence, with $\Delta = 0$, since consumer surplus is higher when prices are lower, $(\hat{\Phi}_M, \hat{\Phi}_m)$ in (22) are indeed the consumer's optimal prices.

Since prices $\hat{\Phi}$ satisfy (9), the expert will choose T_t for $t = m, M$ whenever he learns t. Finally, given $\hat{\Phi}$, the expert receives the same expected profit from choosing (N, T_M) and (N, T_m). Under $(\hat{\Phi}_M, \hat{\Phi}_m)$, from (15) and (16):

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

Thus, under (21), 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 $k > \hat{k}\left(D, \hat{\Phi}\right)$ is for the expert to choose T_M if $z_o < z_o^*$ and T_m if $z_o < z_o^*$. ■

Proof of Proposition 3. First, $(\Phi_M, \Phi_m) = (\Phi_M^a, \Phi_m^a)$ in equilibrium, following directly from the definition of (25). We now proceed to prove (i) and (ii).

(i) With $S(E_T) = -\theta\Phi_m - (1-\theta)(\Phi_M + C)$ and $[S(E_T) - S(N, T_M)] \geq 0$, we have

$$\begin{aligned}
S^a(\Phi_M, \Phi_m)\mid_{\Phi_M = \theta\alpha_o D_o} &= \beta S(E_T) + (1-\beta) S(N, T_M) + (1-\beta) F\left(\hat{k}\right)[S(E_T) - S(N, T_M)] \\
&\geq \beta S(E_T) + (1-\beta) S(N, T_M) \\
&= \beta[-\theta(1-\theta)\alpha_u D_u - (1-\theta)\theta\alpha_o D_o - (1-\theta) C] + (1-\beta)(-\theta z_o - C) \\
&\geq \beta(-\theta(C + z_o) - (1-\theta) C) + (1-\beta)(-\theta z_o - C) = -(C + \theta z_o),
\end{aligned}$$

where the last inequality obtains by using (21).

Next, with $\hat{k} \leq \theta(C + z_o)$, $x \geq (1-\theta) C$ due to the assumption on C from part (i) of (4), and $S(E_T) < -(1-\theta)C$, we have

$$\begin{aligned}
S^a(\Phi_M, \Phi_m)\mid_{\Phi_M < \theta\alpha_o D_o} &= \beta S(E_T) + (1-\beta)(-x) + (1-\beta) F\left(\hat{k}\right)[S(E_T) - (-x)] \\
&\leq \beta(-(1-\theta) C) + (1-\beta)(-x) + (1-\beta) F(\theta(C + z_o))(-(1-\theta) C - (-x)) \\
&= -\beta(1-\theta) C - (1-\beta) x[1 - F(\theta(C + z_o))] - (1-\beta) F(\theta(C + z_o))(1-\theta) C.
\end{aligned}$$

Thus

$$\begin{aligned}
& \max_{\Phi_m} S^a(\Phi_M, \Phi_m)|_{\Phi_M = \theta\alpha_o D_o} - \max_{(\Phi_M, \Phi_m)} S^a(\Phi_M, \Phi_m)|_{\Phi_M < \theta\alpha_o D_o} \\
\geq \quad & -(C + \theta z_o) + (1-\theta) C[\beta + (1-\beta) F(\theta(C + z_o))] + (1-\beta) x[1 - F(\theta(C + z_o))] \geq 0 \\
\iff \quad & x \geq \frac{(C + \theta z_o) - (1-\theta) C[\beta + (1-\beta) F(\theta(C + z_o))]}{(1-\beta)[1 - F(\theta(C + z_o))]} > 0.
\end{aligned}$$

Therefore $\Phi_M^a = \theta\alpha_o D_o$ and $\Phi_m^a \in [0, (1-\theta)\alpha_u D_u]$ if

$$x \geq \max\left\{C + \theta z_o,\ \frac{(C + \theta z_o) - (1-\theta) C[\beta + (1-\beta) F(\theta(C + z_o))]}{(1-\beta)[1 - F(\theta(C + z_o))]}\right\} \equiv x^a.$$

Finally, under $D_o = \frac{(C+z_o)}{(1-\theta)\alpha_o}$ and $D_u = 0$ we have $\Phi_M^a = \frac{\theta(C+z_o)}{1-\theta}$ and $\Phi_m^a = 0$. Thus

$$\hat{k} = \theta\Phi_m^a + (1-\theta)\Phi_M^a = (1-\theta)\frac{\theta(C + z_o)}{1-\theta} = \theta(C + z_o) = k^*.$$

Condition (21) is satisfied because $\alpha_o D_o + \alpha_u D_u = \frac{C+z_o}{(1-\theta)}$, and (9) is also satisfied. Therefore, the expert will choose T_t for $t \in (m, M)$ when he knows t (either initially or by incurring k), and will also incur k efficiently.

(ii) First, recall

$$S^a(\Phi_M, \Phi_m)\mid_{\Phi_M<\theta\alpha_o D_o} = \beta S(E_t) + (1-\beta)(-x) + (1-\beta) F\left(\hat{k}\right)[S(E_t) - (-x)],$$

where $S(E_T) = -\theta\Phi_m - (1-\theta)(\Phi_M + C) < -(1-\theta)C$ and $\hat{k} = \theta\Phi_m + (1-\theta)\Phi_M$. Thus

$$\begin{aligned} & \frac{\partial S^a(\Phi_M, \Phi_m)|_{\Phi_M<\theta\alpha_o D_o}}{\partial \Phi_M} \\ = \; & \beta(-(1-\theta)) + (1-\beta) f\left(\hat{k}\right)(1-\theta)[S(E_t) - (-x)] + (1-\beta) F\left(\hat{k}\right)(-(1-\theta)) < 0 \end{aligned}$$

and

$$\frac{\partial S^a(\Phi_M, \Phi_m)|_{\Phi_M<\theta\alpha_o D_o}}{\partial \Phi_m} = \beta(-\theta) + (1-\beta) f\left(\hat{k}\right)\theta[S(E_t) - (-x)] + (1-\beta) F\left(\hat{k}\right)(-\theta) < 0$$

hold if $(1-\beta) f\left(\hat{k}\right)[S(E_t) - (-x)] - (1-\beta) F\left(\hat{k}\right) < \beta$, which in turn holds if

$$\beta > \arg\max_{k\in[0,\bar{k}]} \frac{f(k)[x - (1-\theta)C] - F(k)}{1 + f(k)[x - (1-\theta)C] - F(k)} \equiv \beta',$$

where $x > (1-\theta)C$ and $\beta' < 1$.

Then, if $\beta > \beta'$, for any D, there can be no equilibrium where $\Phi_M^a < \theta\alpha_o D_o$ and $\hat{k} = \theta\Phi_m + (1-\theta)\Phi_M = \theta(C + z_o) = k^*$. This is because if $\beta > \beta'$ and $\Phi_M^a < \theta\alpha_o D_o$, from $\frac{\partial S^a(\Phi_M,\Phi_m)|_{\Phi_M<\theta\alpha_o D_o}}{\partial \Phi_M} < 0$ and $\frac{\partial S^a(\Phi_M,\Phi_m)|_{\Phi_M<\theta\alpha_o D_o}}{\partial \Phi_m} < 0$ we have $\Phi_M^a = \Phi_m^a = 0$, and hence $\hat{k} = 0 < k^*$.

Next, we show that there exist some β'' and $\beta^a = \max\{\beta', \beta''\} < 1$ such that if $\beta > \beta^a$, there can also be no equilibrium where $\Phi_M^a = \theta\alpha_o D_o$ and $\hat{k} = \theta\Phi_m + (1-\theta)\Phi_M = \theta(C + z_o) = k^*$. Suppose that, to the contrary, there is some D_o for which $\Phi_M^a = \theta\alpha_o D_o$ and $\hat{k} = \theta\Phi_m + (1-\theta)\Phi_M = \theta(C + z_o) = k^*$. Then, when $\beta > \beta^{'}$,

$$\begin{aligned} \frac{\partial S^a(\Phi_M, \Phi_m)|_{\Phi_M=\theta\alpha_o D_o}}{\partial \Phi_m} &= \beta(-\theta) + (1-\beta)\theta f\left(\hat{k}\right)[S(E_T) - S(N, T_M)] + (1-\beta)(-\theta) F\left(\hat{k}\right) \\ &< \beta(-\theta) + (1-\beta)\theta f\left(\hat{k}\right)[S(E_T) + x] + (1-\beta)(-\theta) F\left(\hat{k}\right) < 0, \end{aligned}$$

and hence $\Phi_m^a = 0$. It follows that in order for $\hat{k} = \theta\Phi_m + (1-\theta)\Phi_M = \theta(C + z_o) = k^*$, we have $(1-\theta)\theta\alpha_o D_o = \theta(C + z_o)$ and

$$\max_{\Phi_M,\Phi_m} S^a(\Phi_M, \Phi_m)|_{\Phi_M = \theta\alpha_o D_o} = S^a(\theta\alpha_o D_o, 0)$$

$$\begin{aligned}
&= \beta[-(1-\theta)(\theta\alpha_o D_o + C)] + (1-\beta)[-C - \theta z_o] + (1-\beta)F\left(\hat{k}\right)[-(1-\theta)(\theta\alpha_o D_o + C) + C + \theta z_o] \\
&= \beta[-\theta(C + z_o) - (1-\theta)C] + (1-\beta)[-C - \theta z_o] + (1-\beta)F\left(\hat{k}\right)[-\theta(C + z_o) - (1-\theta)C + C + \theta z_o] \\
&= \beta[-\theta z_o - C] + (1-\beta)[-C - \theta z_o] + (1-\beta)F\left(\hat{k}\right)[-\theta z_o - C + C + \theta z_o] = -(C + \theta z_o).
\end{aligned}$$

But if $\beta > \beta'$, for any D,

$$\max_{\Phi_M,\Phi_m} S^a(\Phi_M, \Phi_m)|_{\Phi_M < \theta\alpha_o D_o} = S^a(0,0) = \beta[-(1-\theta)C] + (1-\beta)(-x).$$

Thus, for $(1-\theta)\theta\alpha_o D_o = \theta(C + z_o)$,

$$\begin{aligned}
&\max_{\Phi_M,\Phi_m} S^a(\Phi_M, \Phi_m)|_{\Phi_M < \theta\alpha_o D_o} - \max_{\Phi_M,\Phi_m} S^a(\Phi_M, \Phi_m)|_{\Phi_M = \theta\alpha_o D_o} \\
&\quad = -\beta[(1-\theta)C] - (1-\beta)x + (C + \theta z_o)
\end{aligned}$$

$$= \beta[x - (1-\theta)C] - x + (C + \theta z_o) > 0 \Leftrightarrow \beta > \frac{x - (C + \theta z_o)}{x - (1-\theta)C} \equiv \beta'',$$

where $\beta'' < 1$. Then, if $\beta > \beta^a = \max\{\beta', \beta''\}$ and $D_o = \frac{(C+z_o)}{\alpha_o(1-\theta)}$, the consumer will optimally offer $\Phi_M = \Phi_m = 0$, resulting in $\hat{k} = 0 < k^*$, which is a contradiction.

We have thus shown that if $\beta > \beta^a$, there exists no D under which $\hat{k} = k^*$ in equilibrium. ■

Appendix B: Noisy Diagnosis

We extend our main model and its analysis in the direction of imperfect diagnosis. Specifically, in the event that the expert does not learn t upon seeing the consumer, he can privately observe only 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 consumer type, that is:

$$\Pr(s_m | t = m) = \sigma = \Pr\{s_M | t = M\}, \qquad \Pr(s_m | t = M) = 1 - \sigma = \Pr\{s_M | t = m\}.$$

We assume

$$\sigma > \underline{\sigma} \equiv \frac{\max\{(1-\theta)(z_u - C), \theta(C + z_o)\}}{(1-\theta)(z_u - C) + \theta(C + z_o)} \geq \frac{1}{2} \tag{30}$$

so that the signal is informative and there exist parameter values under which it is efficient for the expert to exert diagnosis effort.[24] We further assume $\theta > \frac{1}{2}$ so that the consumer's problem is more likely to be minor.[25] Everything else remains the same as in the main model in Section 3. In particular, we impose the minimum-price constraint (12).

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

$$\begin{aligned} W(E_T) &= \theta\left[(1-\sigma)(-C - z_o)\right] + (1-\theta)\left[-\sigma C - (1-\sigma) z_u\right] - k \\ &= \theta\sigma(z_o + C) - (1-\theta)(1-\sigma)(z_u - C) - C - \theta z_o - k. \end{aligned}$$

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

$$k \leq \min\begin{bmatrix} \theta\sigma(C + z_o) - (1-\theta)(1-\sigma)(z_u - C), \\ (1-\theta)\sigma(z_u - C) - \theta(1-\sigma)(C + z_o), \bar{k} \end{bmatrix} \equiv k^{**}(z_o, z_u). \tag{31}$$

For $\sigma < 1$, $k^{**}(z_o, z_u) < k^*(z_o, z_u)$. Imperfect diagnosis reduces the critical value of diagnosis cost. Assumption (30) 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., choosing 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)

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

[25] The analysis for the case with $\theta \leq \frac{1}{2}$ is analogous to $\theta > \frac{1}{2}$.

are the same as in the main model, but the profit from E_T becomes:

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

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:

$$\begin{aligned} k &\leq \min\left\{\begin{array}{c} \left[\theta\sigma + (1-\theta)(1-\sigma)\right](\Phi_m - \Phi_M) + \theta\sigma\alpha_o D_o - (1-\theta)(1-\sigma)\alpha_u D_u, \\ \left[\theta(1-\sigma) + (1-\theta)\sigma\right](\Phi_M - \Phi_m) - \theta(1-\sigma)\alpha_o D_o + (1-\theta)\sigma\alpha_u D_u \end{array}\right\} \\ &\equiv \tilde{k}(D,\Phi). \end{aligned} \tag{32}$$

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

$$\Phi_M - (1-\sigma)\,\alpha_o D_o \geq \Phi_m - \sigma\alpha_u D_u, \qquad \Phi_m - (1-\sigma)\,\alpha_u D_u \geq \Phi_M - \sigma\alpha_o D_o. \tag{33}$$

Note that if a pair of prices (Φ_M, Φ_m) satisfy (33), they also satisfy constraint (9) so that the expert reports truthfully if he learns the consumer's type t without incurring k. Let $\pi(N,T_M) - \pi(N,T_m) = \Delta$. Then using (14), we have

$$\Phi_M - \Phi_m = \Delta + \theta\alpha_o D_o - (1-\theta)\alpha_u D_u. \tag{34}$$

Condition (33) is then equivalent to

$$(1-\sigma-\theta)(\alpha_o D_o + \alpha_u D_u) \leq \Delta \leq (\sigma-\theta)(\alpha_o D_o + \alpha_u D_u). \tag{35}$$

Proposition 5 below characterizes the liability rules that implement the efficient outcome as described in Lemma 2. Whether or not efficiency can be implemented depends on the precision of the expert's noisy signal.

Proposition 5 *(i) If $\sigma \geq \max\{\theta, \underline{\sigma}\}$, the following liability rule results in the efficient outcome in equilibrium:*

$$\tilde{D}_u = \frac{k^{**}(z_o, z_u)}{(1-\theta)(2\sigma-1)\alpha_u}, \qquad \tilde{D}_o = \frac{k^{**}(z_o, z_u)}{\theta(2\sigma-1)\alpha_o}. \tag{36}$$

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

$$\bar{D}_o = \frac{k^{**}(z_o, z_u)}{2\alpha_o\left[(1-\theta)\sigma^2 - \theta(1-\sigma)^2\right]}, \qquad \bar{D}_u = \frac{k^{**}(z_o, z_u)}{2\alpha_u\left[(1-\theta)\sigma^2 - \theta(1-\sigma)^2\right]} \tag{37}$$

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

Proof. Replacing $\Phi_M - \Phi_m$ in (32) by (34), we have

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

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:

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

(i) $\sigma \geq \max\{\theta, \underline{\sigma}\}$. To satisfy (35), Δ can be either positive or negative. We show that $\Delta = 0$ is optimal for the consumer in this case.

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

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

With the given liabilities $(\tilde{D}_o, \tilde{D}_u)$, $\theta(1-\theta)(2\sigma-1)\left(\alpha_o \tilde{D}_o + \alpha_u \tilde{D}_u\right) = k^{**}$, therefore,

$$\begin{aligned}
& S(E_T) - S(N, T_M) = \theta\sigma(\Delta + C) + (1-\theta)(1-\sigma)(\Delta + C) + \theta z_o - k^{**} \\
& \geq \theta\sigma(\Delta + C) + (1-\theta)(1-\sigma)(\Delta + C) + \theta z_o - \left(\theta\sigma(C + z_o) - (1-\theta)(1-\sigma)(z_u - C)\right) \\
& = \theta\sigma\Delta + (1-\theta)(1-\sigma)\Delta + (1-\theta)(1-\sigma) z_u > 0
\end{aligned}$$

Thus, the consumer prefers E_T to (N, T_M). By reducing Φ_M (thus reducing Δ), $\tilde{k}(\tilde{D}, \Phi)$ will rise and the expert incurs the diagnosis cost more often and the consumer pays a lower price. In the case that the expert learns t immediately without diagnosis effort, keeping everything else the same, $\Delta = 0$ implies a lower price for the consumer than $\Delta > 0$. Thus, if $\Delta > 0$, it is optimal for the consumer to reduce Δ by reducing Φ_M.

Similarly, one can show that given $\tilde{D}$, $\Delta < 0$ 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 (12), therefore, the consumer's optimal price must be

$$\hat{\Phi}_M = \theta\alpha_o\tilde{D}_o, \quad \hat{\Phi}_m = (1-\theta)\alpha_u\tilde{D}_u. \tag{38}$$

From (32), using the optimal prices (38), the expert incurs k if and only if $k \leq \tilde{k}\left(\tilde{D}, \hat{\Phi}\right) = \theta(1-\theta)(2\sigma-1)\left(\alpha_u\tilde{D}_u + \alpha_o\tilde{D}_o\right) = k^{**}$. Thus, the efficient outcome is indeed achieved with liability $(\tilde{D}_o, \tilde{D}_u)$.

(ii) If $\theta > \underline{\sigma}$, $\max\{\tilde{\sigma}, \underline{\sigma}\} < \sigma < \theta$ is a non-empty interval because $\theta > \tilde{\sigma} = \frac{\theta - \sqrt{\theta - \theta^2}}{2\theta - 1}$ for $\theta > \frac{1}{2}$.

Since $\sigma < \theta$, satisfying (35) requires $\Delta < 0$. From (32), we get

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

Note that $\tilde{k}(D,\Phi)$ increases in Δ. Following the same procedure in part (i), one can show that given $(\bar{D}_o, \bar{D}_u)$, $S(E_T) - S(N, T_m) > 0$ and the largest Δ is optimal for the consumer, that is

$$\Delta^*(D_o, D_u) = (\sigma - \theta)(\alpha_o D_o + \alpha_u D_u).$$

Accounting for constraint (12), the equilibrium prices must be

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

Then, the expert exerts diagnosis effort if and only if k does not exceed

$$\begin{aligned}\bar{k}\left(\bar{D},\bar{\Phi}\right) &= (\theta(1-\sigma) + (1-\theta)\sigma)\,\Delta^*(\bar{D}_o,\bar{D}_u) + \theta(1-\theta)\,(2\sigma-1)\left(\alpha_o\bar{D}_o + \alpha_u\bar{D}_u\right)\\ &= \left[(1-\theta)\sigma^2 - \theta(1-\sigma)^2\right]\left(\alpha_o\bar{D}_o + \alpha_u\bar{D}_u\right) = k^{**}.\end{aligned}$$

Thus, liability rule $(\bar{D}_o, \bar{D}_u)$ indeed implements the efficient outcome.

(iii) If $\tilde{\sigma} > \underline{\sigma}$, $\underline{\sigma} < \sigma \le \tilde{\sigma}$ is a non-empty interval. Note that $\sigma \le \tilde{\sigma} = \frac{\theta - \sqrt{\theta-\theta^2}}{2\theta-1}$ is equivalent to $\sigma^2(1-\theta) - \theta(1-\sigma)^2 \le 0$. For any pair of prices that satisfy (35), the expert exerts diagnosis effort if k does not exceed

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

where the first inequality is obtained by replacing Δ with its upper bound $(\sigma-\theta)(\alpha_o D_o + \alpha_u D_u)$ in (35). Thus, there exists no liability rule under which the equilibrium prices will ensure the efficient outcome with honest reporting and efficient effort by the expert. ■

Thus, the efficient outcome can be implemented if σ is sufficiently large, that is, $\sigma > \max\{\tilde{\sigma}, \underline{\sigma}\}$. Because of constraint (35), the liability rules that implement efficiency differ when

$\sigma \geq \max\{\theta, \underline{\sigma}\}$ or $\max\{\tilde{\sigma}, \underline{\sigma}\} < \sigma < \theta$. But if σ is below the threshold, $\tilde{\sigma}$, efficiency cannot be implemented.

Intuitively, when $\sigma \geq \max\{\theta, \underline{\sigma}\}$, $\Delta = 0$ 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 $\max\{\tilde{\sigma}, \underline{\sigma}\} < \sigma < \theta$, $\Delta < 0$ in order for the truthful reporting incentive (35) to hold. In this case, the equilibrium prices for a given liability rule (D_o, D_u) are

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

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 consumer'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 (35) and the upper bound of Δ in (35), the expert would exert diagnosis effort only if k is below

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

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.

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