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Abstract

We analyze a credence goods market where the expert may have a high or low cost in repairing a major problem, under the assumptions that i) the expert is liable for the outcome of the treatment (liability), and ii) the type of treatment is (or is not) verifiable by the consumer (verifiability). We show that, with just liability, an inefficiency arises because not all major problems are resolved in equilibrium. With both verifiability and liability, another inefficiency arises because minor problems are sometimes fixed through costly major treatments (overtreatment). Adding verifiability improves social welfare because a major problem is resolved with a higher probability, and the gain dominates wasteful overtreatment costs.

JEL classifications: D21, D82, L23

Keywords: Credence Goods, Treatment Costs, Liability, Verifiability

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1 Introduction

Consider a credence goods market in which an expert (he) provides professional services to a consumer (she). Because of his expertise, the expert knows more about the nature of the consumer's problem—whether the problem is a major one that requires a major treatment or a minor one that requires a minor treatment. After the service has been provided, the consumer cannot ascertain whether or not it was appropriate for her problem (Darby and Karni, 1973). For example, the water tank of the consumer's car was leaking, either because of a broken pump (a major problem) or a broken connection (a minor problem), and the mechanic recommended replacing the pump (a major treatment). After the repair, the car functioned well. However, the consumer will never know whether replacing a connection (a minor treatment) would have been sufficient to solve her problem, or whether the replacement of the pump was necessary.

The expert's information advantage and the consumer's lack of knowledge about the appropriate treatment lead to cheating incentives for the expert. The expert may overtreat the consumer by providing a major treatment for a larger profit even if a minor treatment is sufficient, or he may undertreat the consumer by providing a minor treatment that does not solve her problem, or he may overcharge her by charging a price for unprovided major treatment.

The literature has extensively analyzed how to eliminate the expert's cheating incentives in various settings. Liability and verifiability are among the most important institutional assumptions underlying the credence goods market.[1] Under the assumption of liability, the expert is liable for the treatment outcome and thus cannot provide an inadequate treatment that does not resolve the consumer's problem. Under verifiability, the type of treatment provided is costlessly verifiable to the consumer. Thus, the expert cannot charge the consumer for an unprovided treatment. Both institutions are legally enforceable through hard evidence. Liability can be enforced through punishment of the expert if he fails to solve the consumer's problem. Verifiability can be enforced by creating hard evidence of the treatment process; for example, by videotaping the treatment process — a common practice for many service providers.

While liability has the apparent advantage of precluding undertreatment, the role of verifia-

[1] See Dulleck and Kerschbamer (2006) for a review of the early literature and Balafoutas and Kerschbamer (2020) for a review of more recent contributions.

bility in mitigating market inefficiency is less clear. If verifiability does not hold, the expert may cheat through overcharging; if verifiability holds, the expert can cheat only through overtreatment. Overcharging is not directly harmful to social welfare because it involves a pure monetary transfer between the consumer and the expert; overtreatment, though, imposes wasteful costs when a minor problem is repaired through a more costly major treatment. Given the controversial effect of verifiability, a natural question arises: is it socially beneficial to impose verifiability on top of liability? This is a policy-relevant issue because verifiability can be imposed through mandatory transparency of the treatment process in credence goods markets. For instance, when physicians submit a claim for services provided, they should be able to support their claim with accurate and complete medical records and documentation of the services provided.[2] Automotive repair dealers are usually requested to provide an invoice that records in detail all service work completed and all parts supplied. Replaced parts are returned to the customer, or shown to the customer if they are to be returned to the manufacturer.[3]

We evaluate how verifiability affects the interaction between the expert and the consumer in a credence goods market in which the expert is liable for the treatment outcome. The setting has the feature that the expert may have a high or low treatment cost in repairing a major problem, while the treatment cost for a minor problem is normalized to zero.[4] Moreover, the consumer suffers a larger loss from an unresolved major problem than from an unresolved minor problem. In the baseline model where the expert's cost types are observable, we derive the main result that imposing verifiability on top of liability improves social welfare, and we illustrate the main intuition for this result. In an extension with unobservable expert types, we prove the robustness of this insight and further illustrate how the composition of the expert types and the existence of asymmetric information affect the role of verifiability.

[2]See "Medicare Fraud & Abuse: Prevent, Detect, Report" by the Medicare Learning Network (January 2021) for medical practice in the United States. https://www.cms.gov/Outreach-and-Education/Medicare-Learning-Network-MLN/MLNProducts/Downloads/Fraud-Abuse-MLN4649244.pdf.

[3]See "Chapter 20.3 Automotive Repair" of California Laws - Business Procedure Code. https://law.justia.com/codes/california/2016/code-bpc/division-3/chapter-20.3/article-3/. Dulleck and Kerschbamer (2006) provide an illuminating discussion of the institutional assumptions underlying the credence goods market, and the common business practices and regulations that uphold these assumptions.

[4]In section 5, we show that the results remain qualitatively the same if the treatment costs for a minor problem are also positive and heterogeneous.

When the expert types are observable, the consumer knows the expert's treatment cost when she visits the expert. In the setting with just liability, there exists a unique perfect Bayesian equilibrium in which the expert makes honest recommendations regardless of the level of his treatment cost. However, in order to prevent the expert from overcharging, the consumer rejects an offer to repair her problem at a high price with a positive probability. Although overcharging does not occur in equilibrium, the outcome is socially inefficient because a major problem remains unresolved with a positive probability, and the consumer suffers a resulting loss. When verifiability is imposed on top of liability, there exist two classes of equilibria that are payoff-equivalent for the expert. One class is efficient: the expert provides honest recommendations after posting a price list that satisfies an equal-profit margin between the two types of treatment. The other class is inefficient: the expert posts a price list that does not satisfy the equal-profit margin; the expert then overtreats the consumer with a positive probability, and the consumer rejects a recommendation of major treatment with a positive probability. While the efficient equilibrium leads to an obvious increase in social welfare relative to the outcome under just liability, the same holds true for the class of inefficient equilibria — despite the social waste from overtreatment and the social loss from unresolved major problems. When verifiability is also in place, the consumer accepts a recommendation of major treatment with a higher probability, and the social gain from the increased probability of a major problem being resolved dominates the social waste from overtreatment. Thus, adding verifiability on top of liability is socially beneficial.

When the expert types are unobservable, different types have heterogeneous treatment costs, which are the expert's private information.[5] In the setting with just liability, the expert does not have to incur the cost of major treatment when he charges the consumer a high price. As a result, the equilibrium under observable expert types is still supported and the existence of asymmetric information has no impact on the equilibrium outcome. When both liability and verifiability are in place, neither a separating equilibrium nor an equilibrium with the efficient outcome exists. However, there exist multiple price-pooling equilibria. We apply the intuitive criterion (Cho and Kreps, 1987) to rule out equilibria supported by incredible off-equilibrium path beliefs, and the

[5] It is not uncommon for an expert to hold private information about his treatment cost. For example, a surgeon privately knows how costly it is for him to carry out a heart operation. A mechanic privately knows how skilled he is and how many hours it takes him to fix an engine problem.

payoff-dominance principle to select the most plausible equilibria from the expert's point of view. Through these refinements, we are able to obtain a unique price-pooling equilibrium in which either the low-cost type overtreats with probability one, or both expert types provide an honest treatment. Since a low-cost type has a larger incentive to overtreat the consumer than a high-cost type, the equilibrium outcome depends on the composition of the expert types and the prior distribution of the nature of the consumer's problem.

When the probability of the low-cost type is large, or the probability is moderate and the consumer's problem is likely to be major, the two expert types post the same highest possible prices for both minor and major treatments. The expert then makes honest recommendations, but the consumer disciplines the expert's overtreating incentive by rejecting a recommendation of major treatment with a positive probability. When the probability of the low-cost type is small, or the probability is moderate and the consumer's problem is unlikely to be major, both expert types post relatively low prices. The low-cost type then overtreats the consumer with probability one, and the high-cost type provides an honest treatment; however, the consumer always accepts the expert's recommendation because the posted prices are sufficiently low. Thus, in the setting with both liability and verifiability, inefficiency occurs in the form either of social waste from overtreatment or of social loss from an unrepaired major problem. (Under observable expert types, these two types of inefficiency occur concurrently.) However, compared with the setting with just liability, the social welfare level is always higher because the consumer accepts a recommendation of major treatment with a higher probability, and the benefits from the increased probability of a major problem being repaired dominate the social waste from overtreatment.

One interesting observation is that the existence of asymmetric information about the expert's treatment costs may increase social welfare when both liability and verifiability are in place. Under unobservable expert types, when the expert has a small probability of being a low-cost type, the overtreating incentive of the high-cost type drives down the equilibrium price for major treatment. In this case, the consumer always accepts a recommendation for major treatment, and a major problem is always repaired. By contrast, a major problem remains unresolved with a positive probability in the inefficient equilibria under observable expert types. Therefore, when the expert is unlikely to be a low-cost type, the social welfare level under unobservable expert types can be higher than under observable expert types.

The remainder of the paper is organized as follows. In the rest of this section, we relate our paper to the credence goods literature. Section 2 presents the setting in which the expert may be a low-cost or a high-cost type repairing a major problem, and the consumer's losses from an unrepaired major and minor problem are different. Section 3 analyzes the market equilibria in the setting with just liability and in the setting with both liability and verifiability, assuming the expert types are observable to the consumer. Section 4 analyzes the equilibria when the expert types are unobservable to the consumer and the posted prices convey signals about the expert's private information. In Section 5 we discuss the assumption of allowing positive and heterogeneous costs for a minor treatment, and the role of verifiability if the expert market is competitive. Concluding remarks can be found in Section 6. The Appendix contains all the proofs not provided in the main text.

Related literature There is an extensive literature analyzing how different information structures, market institutions, and characteristics affect the interaction between the expert and the consumer in a credence goods market. While most studies assume liability and/or verifiability, and explore how to provide incentives to experts in different environments,[6] several focus on how the assumption of liability and/or verifiability affects market performance and social welfare. Fong (2005) shows that, under the assumption of liability, the equilibrium outcome is inefficient if the expert and the consumer cannot commit to trading. The consumer rejects a high-price offer with a positive probability in order to eliminate the expert's incentives for overcharging. Dulleck and Kerschbamer (2006) review the result in Fong (2005) and other earlier contributions in a unifying framework. They show that either verifiability or liability is sufficient for an efficient outcome if the expert and the consumer can commit to trading, while inefficiencies and expert cheating may arise even if liability or verifiability is in place, when there is no commitment. Fong

[6]See, for example, Pitchik and Schotter (1987), Wolinsky (1995), Alger and Salanié (2006), Emons (1997, 2001), Hyndman and Ozerturk (2011), Frankel and Schwarz (2014), Dulleck et al. (2015), Bester and Dahm (2018), Jost et al. (2021), Chen et al. (2022). Bester and Dahm (2018) assume verifiability holds and analyze the optimal contract when the consumer has a subjective evaluation of the treatment outcome. Chen et al. (2022) assume verifiability holds and analyze the optimal design of liability rules in expert markets that share some features of credence goods.

et al. (2014) compare the equilibrium outcomes under the assumption of verifiability versus those under liability. They show that, for some parameter configurations, the equilibrium outcome is more efficient under liability than under verifiability. Balafoutas and Kerschbamer (2020, section 4.3) provide a detailed discussion of the contributions that have analyzed the role of liability and verifiability since Dulleck and Kerschbamer (2006).[7] Our study complements these contributions by focusing on the welfare effect of imposing verifiability on top of liability and by highlighting the new insight that, although inefficiencies and expert cheating might occur in equilibrium, verifiability can always improve the market outcome by increasing the probability with which a major problem is repaired.

Our analysis of the scenario with unobservable treatment costs is also related to the contributions that consider how expert heterogeneity affects the credence goods market. In particular, Hilger (2016) incorporates asymmetric information about treatment costs into a credence goods model, in a setting without liability but with consumer-side commitment, and shows that various types of mistreatments may occur in equilibrium under the assumption of verifiability. Our analysis contains one critical message that Hilger (2016) misses: adding verifiability on top of liability in the credence goods market improves social welfare. Dulleck and Kerschbamer (2009) analyze a setting with an expert who can diagnose the consumer's problem and a discounter who cannot diagnose but has an incentive to free-ride on the expert's diagnosis effort. Liu (2011) analyzes a setting with the coexistence of conscientious and selfish experts under the assumption of liability, and shows that the presence of a conscientious expert may result in more fraudulent behavior by the selfish expert. Liu et al. (2020) assume that experts have different diagnostic abilities, and show that efficient and inefficient equilibria coexist under the assumption of verifiability. In contrast to these contributions, we focus on how heterogeneous treatment costs affect the expert's fraudulent behavior, and analyze the equilibria under liability with and without verifiability.

[7] In a large-scale experiment, Dulleck et al. (2011) show that the performance of credence goods markets is very poor in the presence of verifiability relative to the presence of liability.

2 The Model

We consider a credence goods market with a monopoly expert and a representative consumer. The consumer has a problem that can be minor ($\theta = m$) or major ($\theta = M$) with $\Pr\{\theta = M\} = 1 - \Pr\{\theta = m\} = q \in (0, 1)$. The consumer's utility is $-\ell_M$ if a major problem remains unresolved and $-\ell_m$ if a minor problem remains unresolved, with $\ell_M > \ell_m > 0$. If her problem is repaired at price P, the consumer's net utility is $0 - P = -P$. The consumer knows the distribution of θ but cannot tell whether $\theta = m$ or $\theta = M$ due to lack of expertise.[8]

On the other hand, the expert can privately learn the realization of θ by performing a costless diagnosis. He can also provide two treatments $T \in \{T_m, T_M\}$, in which treatment T_m fixes only a minor problem but treatment T_M fixes both types of problem. The expert has two cost types, $t \in \{L, H\}$. Both expert types perform T_m at zero cost, but a low-cost type performs treatment T_M at cost $c_L = c$ while a high-cost type performs treatment T_M at cost $c_H = \alpha c$, with $\alpha > 1$. Parameter α measures the cost disparity between the two expert types. In the case of observable expert types, both the expert and the consumer learn the realization of t. In the case of unobservable expert types, the expert privately learns the realization of type t and the consumer only knows its prior distribution $\Pr\{t = L\} = 1 - \Pr\{t = H\} = x \in (0, 1)$.

We make the following assumptions regarding the parameters

$$\ell_m < \bar{\ell} < c < \alpha c < \ell_M \qquad \text{in which} \qquad \bar{\ell} = q\ell_M + (1-q)\ell_m, \tag{1}$$

$$\ell_M - \alpha c > \ell_m. \tag{2}$$

Assumption (1) ensures that it is efficient for both expert types to fix a major problem; moreover, the cost of repairing a major problem is higher than the *ex ante* expected loss to the consumer. Therefore, there exists no uniform price for T_m and T_M that is acceptable to the

[8] We could alternatively assume that the consumer enjoys utility $v_m = \ell_m$ when a minor problem is resolved, $v_M = \ell_M$ when a major problem is resolved, and 0 if her problem is unresolved. The analysis is qualitatively the same as with our current setting.

consumer while at the same time always ensuring nonnegative profits for both expert types.[9] Assumption (2) ensures that repairing a major problem is more socially valuable than repairing a minor problem for both expert types.[10] Following the literature, for example, Dulleck and Kerschbamer (2006), we define the institutions of liability and verifiability as follows.

Definition 1 ***Liability****: the expert is liable for repairing the consumer's problem and the consumer can verify ex post whether her problem is resolved or not, at zero cost.*

Verifiability*: the type of treatment that the consumer receives is costlessly verifiable.*

Under the assumption of liability, the expert cannot resolve a major problem through a minor treatment (T_m) because it cannot fix the problem. As a result, *undertreatment* is precluded by liability. However, *overcharging* is possible—the expert may charge the consumer for T_M while providing treatment T_m. Note that the expert has no incentive to overtreat because, for the expert, overtreating is always dominated by overcharging, since overtreating incurs the treatment cost while overcharging delivers the major treatment price without actually incurring the treatment cost. Thus, under liability, the interaction between the expert and the consumer can be modeled as the expert offering to repair the consumer's problem at a certain price.

Timing of the game under liability is as follows:

1. Nature draws the expert's type $t \in \{L, H\}$ (with probability x and $1 - x$ respectively), which is revealed to the expert. Expert of type t posts price $P^t \equiv (P^t_m, P^t_M)$ with $P^t_M \geq P^t_m$ and $P^t_M \geq c_t$.[11]

2. The consumer observes the posted prices and visits the expert with her problem.

[9] If $\ell_m < c < \alpha c \leq \bar{\ell} < \ell_M$, then there exists a uniform price equilibrium where both expert types provide honest recommendations which are always accepted by the consumer, and the equilibrium outcome is socially efficient. If $c < \bar{\ell} < \alpha c$, the low-cost expert could always post price $\bar{\ell}$, make honest recommendations which the consumer always accepts under observable treatment costs. The analysis is qualitatively similar to that in Section 4 if the treatment costs are unobservable.

[10] In the example of the leaking water tank in the Introduction, this would imply that repairing a broken pump is more socially valuable than repairing a broken connection. For an example in Medicare, this would imply that curing pneumonia is more socially valuable than curing a regular flu.

[11] $P^t_M \geq P^t_m$ and $P^t_M \geq c_t$ are imposed to ensure that the price for the more costly treatment is higher and *ex post* the expert does not suffer a loss by providing a major treatment T_M. We assume the expert must provide a treatment once the consumer accepts his recommendation. In an alternative setup in which the expert is free to set $P^t_M < c_t$ but can refuse to provide a treatment after seeing the consumer, the analysis is much more complicated without bringing additional new insights.

3. The expert privately learns θ, the nature of the consumer's problem, and recommends solving the problem at price $R \in \{P_m, P_M\}$.

4. The consumer observes the expert's recommendation, updates her belief about the nature of her problem given R, and decides whether to accept or reject the expert's recommendation. If the consumer accepts R, the expert repairs the consumer's problem and receives R. If she rejects the recommendation, her problem remains unresolved, and the expert receives zero payment.

When verifiability holds, the expert cannot charge the consumer a price for an unperformed treatment, and *overcharging* is precluded. Thus, with both liability and verifiability in place, the above timing of the game is slightly different: at stage 3, the expert recommends a treatment ($R \in \{T_m, T_M\}$) to the consumer; at stage 4, if the recommended treatment is accepted, the expert will perform the recommended treatment and receive the posted price for that treatment. When both liability and verifiability hold, overtreatment may arise. The expert may repair a minor problem through T_M while the consumer *ex post* learns only that her problem has been resolved but cannot determine whether T_M or T_m was the appropriate treatment for her problem.

In the next section, we will first analyze a baseline model in which the expert types are observable to the consumer, meaning that when the consumer visits the expert at stage 2, she knows whether the expert has a high or low cost in repairing a major problem. This case provides useful insight into the role of verifiability when there is no asymmetric information about treatment costs. We will then proceed to the case of unobservable expert types and investigate how asymmetric information about treatment costs affects the market equilibrium and the role of verifiability. Given the restrictions on prices, $P_M^t \geq P_m^t$ and $P_M^t \geq c_t$, the consumer never accepts an offer to repair her problem at price $P_M^t > \ell_M$ or $P_m^t > \ell_m$. Moreover, without more information about her problem, the consumer would not accept a recommendation if $P_M^t = P_m^t \geq \bar{\ell}$ due to $c_t > \ell_m$ by assumption (1). Thus, we can focus on prices P^t for $t \in \{L, H\}$ that satisfy

$$(P_m^t, P_M^t) \in [0, \ell_m] \times [c_t, \ell_M] \tag{3}$$

in the subsequent analysis. We say that an equilibrium is *unique* if the choices of prices, the expert's recommendation policies, and the consumer's acceptance policy are uniquely determined.

We apply the following tie-breaking rules throughout the analysis in the characterization of equilibria: 1) if the consumer is indifferent between multiple rates of accepting the expert's recommendation, she chooses the largest one so that her problem is repaired with the largest probability; 2) if the expert is indifferent between multiple recommendation policies, he chooses the one with which he provides an honest recommendation with the largest probability.[12]

3 Observable Expert Types

When the expert types are observable, any price vector $P^t = (P^t_m, P^t_M)$ posted by an expert of type t leads to a *recommendation subgame* in which the expert chooses his recommendation policy (σ^t), and the consumer chooses her acceptance policy (λ^t). We first characterize the equilibria of the recommendation subgame and then solve backward for the expert's optimal choice of prices at stage 1. Since the analysis for the two expert types is independent and identical, we drop the superscript t whenever there is no confusion.

3.1 Equilibrium under Liability

Under the assumption of liability, the expert is obliged to fix the consumer's problem if she accepts the expert's recommendation. However, the treatment which the expert performs to fix the problem is not verifiable to the consumer.

In the recommendation subgame, when the consumer's problem is major ($\theta = M$), treatment T_M has to be performed to fix the problem; therefore, it is optimal for the expert to recommend $R = P_M$. However, when $\theta = m$, the expert can recommend repairing the problem at either price P_M or P_m without actually performing T_M. Thus, the expert's recommendation policy can be described as $\sigma = \Pr\{R = P_M \mid \theta = m\}$: the probability that the expert offers to repair the consumer's problem at P_M when $\theta = m$.

On observing R, the consumer updates her belief about the nature of her problem and decides whether to accept the recommendation. If $R = P_m$, the consumer infers that her problem must be

[12] We make explicit where the tie-breaking rule is used.

minor and accepts the recommendation with probability one. If $R = P_M$, since it is possible that the expert is recommending P_M while her problem is in fact minor, the consumer may choose to reject the offer with a positive probability in order to discipline the expert. Thus, the consumer's strategy λ can be described as the probability with which she accepts a recommendation of $R = P_M$.

To analyze the equilibria in the recommendation subgame following price $P = (P_m, P_M) \in [0, \ell_m] \times [c_t, \ell_M]$, for $t \in \{L, H\}$, we consider the following two cases in sequence: $P_M < \ell_M$ and $P_M = \ell_M$.

Case 1: $P_M < \ell_M$. In any equilibrium, the consumer's acceptance policy must be interior; that is, $\lambda \in (0, 1)$. If $\lambda = 1$, the expert would always offer P_M for $\theta = m$, since $P_M > P_m$, and this leads to a negative expected utility for the consumer because $\bar{\ell} - P_M \leq \bar{\ell} - c_t < 0$. Moreover, $\lambda = 0$ does not form an equilibrium either, because the expert will always recommend $R = P_m$ if $\theta = m$, and then whenever the expert offers $R = P_M$, the consumer will infer that her problem is major and will thus accept the offer instead. In equilibrium, the expert's recommendation policy σ makes the consumer indifferent between accepting and rejecting a recommendation $R = P_M$:

$$\underbrace{-P_M}_{\text{Consumer's utility from accepting } P_M} = \underbrace{\frac{q}{q + (1-q)\sigma}(-\ell_M) + \frac{(1-q)\sigma}{q + (1-q)\sigma}(-\ell_m)}_{\text{Consumer's utility from rejecting } P_M}. \tag{4}$$

The right-hand side of (4) increases with σ and takes the value $-\ell_M$ when $\sigma = 0$, and $-\bar{\ell}$ when $\sigma = 1$. Since $\bar{\ell} < c_t \leq P_M < \ell_M$, it follows that $\sigma \in (0, 1)$ in equilibrium. The consumer's acceptance policy λ makes the expert indifferent between offering P_m and P_M when $\theta = m$:

$$\underbrace{P_m}_{\text{Expert's payoff when offering } P_m} = \underbrace{\lambda P_M}_{\text{Expert's payoff when offering } P_M}. \tag{5}$$

Therefore, for the given price $(P_m, P_M) \in [0, \ell_m] \times [c_t, \ell_M)$, there is a unique equilibrium in the recommendation subgame with

$$\sigma = \frac{q(\ell_M - P_M)}{(1-q)(P_M - \ell_m)}, \quad \lambda = \frac{P_m}{P_M}. \tag{6}$$

Case 2: $P_M = \ell_M$. Using arguments similar to those in case 1, we can rule out $\lambda = 1$ as a part of an equilibrium. Differently from case 1, we cannot rule out $\lambda = 0$. It follows straightforwardly that any pair of (σ, λ) with $\sigma = 0$ and $\lambda \in [0, \frac{P_m}{P_M}]$ are mutually best responses in the recommendation subgame. Applying the tie-breaking rule that the consumer chooses the largest acceptance rate when she is indifferent between multiple rates in order that her problem be resolved with the largest probability, we arrive at the unique equilibrium of the recommendation subgame for price $(P_m, P_M) \in [0, \ell_m] \times \{\ell_M\}$:

$$\sigma = 0, \qquad \lambda = \frac{P_m}{P_M}. \tag{7}$$

In both cases, the equilibrium σ and λ are affected by the expert's cost heterogeneity only through prices. Moreover, if the two expert types have posted the same price list, then the equilibrium in the recommendation subgame is also identical. Using (6) and (7), we can write the expected profit of a type t expert from posting price vector $(P_m^t, P_M^t) \in [0, \ell_m] \times [c_t, \ell_M]$ as

$$\Pi^t(P^t) = q\lambda^t[P_M^t - c_t] + (1-q)P_m^t = P_m^t - qc_t\frac{P_m^t}{P_M^t}, \text{ for } t = L, H. \tag{8}$$

Since $\Pi^t(P^t)$ monotonically increases in P_m^t and P_M^t, the optimal prices are uniquely given by $(P_m^t, P_M^t) = (\ell_m, \ell_M)$. Proposition 1 below summarizes the *unique* perfect Bayesian equilibrium under the assumption of liability.

Proposition 1 *Under the assumption of liability there exists a unique perfect Bayesian equilibrium where both expert types post the same price list* $P^t = (\ell_m, \ell_M)$*. Both types make an honest recommendation* ($\sigma^t = 0$) *at stage 3. The consumer accepts a recommendation* $R = \ell_M$ *with probability* $\lambda = \ell_m/\ell_M$*. The equilibrium profits of the two types are* $\tilde{\Pi}^L = \ell_m - qc\frac{\ell_m}{\ell_M}$ *and* $\tilde{\Pi}^H = \ell_m - q\alpha c\frac{\ell_m}{\ell_M}$.

Under liability, both expert types post the highest possible prices for T_M and T_m. Given such prices, both types make honest recommendations in equilibrium: an expert offers to repair the consumer's problem at $R = P_M$ when $\theta = M$ and offers $R = P_m$ when $\theta = m$. The outcome is nevertheless inefficient due to a possibly unrepaired major problem, because the consumer rejects

$R = P_M$ with probability $1 - \lambda = 1 - \frac{\ell_m}{\ell_M}$ to discipline the expert's overcharging incentive.

Resolving a major problem incurs an expected cost $xc + (1-x)\alpha c$, and the consumer suffers a loss $-\ell_M$, when a major problem remains unresolved. A minor problem is always repaired at zero cost. Thus, the *ex ante* social welfare level in the setting with just liability is given by:

$$\begin{aligned}\tilde{W}_L &= -q(1 - \frac{\ell_m}{\ell_M})\ell_M - q\frac{\ell_m}{\ell_M}\left[xc + (1-x)\alpha c\right] \\ &= -q(\ell_M - \ell_m) - q\frac{\ell_m}{\ell_M}\left[xc + (1-x)\alpha c\right]. \end{aligned} \tag{9}$$

3.2 Equilibria under Liability and Verifiability

In this subsection, we assume that both liability and verifiability hold, in order to illustrate the role of verifiability. When the consumer can verify the type of treatment she receives, the expert must perform T_M and incur the treatment cost if he recommends repairing the consumer's problem at price P_M. Therefore, at stage 3, the expert chooses whether to recommend T_m or T_M for the consumer's problem. Since a major problem can only be resolved through T_M, the expert's recommendation policy can be represented by $\sigma^t = \Pr\{R = T_M | \theta = m\}$: the probability with which a type t expert recommends treatment T_M when the consumer's problem is $\theta = m$.

The consumer's strategy specifies the probability with which she accepts the expert's recommendation. Due to the assumption of liability, when the consumer is recommended T_m, she can infer that her problem must be minor and thus accepts the recommendation if $P_m \leq \ell_m$. However, if she receives a recommendation $R = T_M$, there is some probability that her problem is actually minor. In this case, the consumer may have an incentive to reject the recommendation in order to discipline the expert. Thus, the consumer's strategy can be described as $\lambda^t = \Pr\{\text{Accept} \mid R = T_M\}$: the probability with which the consumer accepts a recommendation of T_M when she faces a type t expert.

To illustrate the main difference produced by adding verifiability, suppose that $(P_m^t, P_M^t) \in [0, \ell_m] \times (P_m^t + c_t, \ell_M)$. Then the unique equilibrium of the recommendation subgame has $\sigma^t \in (0,1)$ and $\lambda^t \in (0,1)$. While the consumer's indifference condition remains the same as (4), the expert's indifference condition is now affected by the treatment costs

$$P_m^t = \lambda^t (P_M^t - c_t) \tag{10}$$

because he needs to incur c_t when his recommendation of T_M is accepted. As a result, for the same price list, the consumer accepts $R = T_M$ with a higher probability in the setting with both liability and verifiability than she accepts $R = P_M$ in the setting with just liability. This distinction leads to important differences in the equilibrium outcomes.

Note that, when $P_M^t = \ell_m + c_t$, the expert is indifferent between an honest recommendation and overtreatment, so any $\sigma^t \in [0,1]$ is optimal for the expert, while when $P_M^t = \ell_M$, the consumer is indifferent between accepting and rejecting $R = T_M$, and any $\lambda^t \in [0,1]$ is optimal for the consumer. Accounting for these corner cases and applying the expert's and the consumer's tie-breaking rules where applicable, we arrive at the following results.

Proposition 2 *When both liability and verifiability hold, there are two classes of perfect Bayesian equilibria.*

(1) A continuum of inefficient equilibria with $(P_m^t, P_M^t) \in \{\ell_m\} \times (\ell_m + c_t, \ell_M]$. In the recommendation subgame following (P_m^t, P_M^t), the expert and the consumer choose respectively

$$\sigma^t = \frac{q(\ell_M - P_M^t)}{(1-q)(P_M^t - \ell_m)}, \quad \lambda^t = \frac{\ell_m}{P_M^t - c_t}. \tag{11}$$

(2) A unique efficient equilibrium with $(P_m^t, P_M^t) = (\ell_m, \ell_m + c_t)$. In the recommendation subgame, the expert and the consumer choose $\sigma^t = 0$ and $\lambda^t = 1$.

The expert's expected profits are the same in the two classes of equilibria: $\tilde{\Pi}^t = \ell_m$ for $t \in \{L, H\}$.

In part (1) of Proposition 2, both expert types overtreat the consumer in equilibrium, and the consumer accepts a recommendation of T_M with a probability strictly smaller than one. In part (2), given $P_M^t = \ell_m + c_t$, the expert is indifferent between overtreating and an honest recommendation because the profit margins from providing T_m and T_M are equal. The expert selects an honest recommendation ($\sigma^t = 0$) by the tie-breaking rule.

3.3 The Benefits of Verifiability

In the setting with just liability, cheating occurs in the form of overcharging, while if verifiability is added to liability, it occurs in the form of overtreatment. Overcharging does not harm social welfare directly because it involves a monetary transfer between the expert and the consumer. However, overtreatment directly incurs social waste because a minor problem is repaired through more costly major treatment. From this, one might naturally conclude that imposing verifiability on top of liability can lead to a decrease in social welfare. We show that this is not the case: imposing verifiability on top of liability is always socially beneficial, and this holds for both classes of equilibria in Proposition 2.

Corollary 1 *With observable expert types, imposing verifiability on top of liability is socially beneficial.*

The efficient equilibrium in Proposition 2 achieves (*ex ante*) the efficient level of social welfare

$$\tilde{W}_{LV} = -q(xc + (1-x)\alpha c) \tag{12}$$

which is larger than the expected social welfare $\tilde{W}_L$ in (9) in the setting with just liability.

For the class of inefficient equilibria in Proposition 2, an expert overtreats with probability σ^t and the consumer accepts a recommendation of T_M with probability λ^t given in (11). In these equilibria, social losses come from the wasteful treatment cost of repairing a minor problem through T_M and the consumer's loss from an unresolved problem. A minor problem is repaired at zero cost with probability $1-\sigma^t$, is repaired through the more expensive treatment T_M with probability $\sigma^t\lambda^t$, and remains unrepaired with probability $\sigma^t(1-\lambda^t)$. Thus, the expected social loss associated with a minor problem is $(1-q)\sigma^t(\lambda^t c_t + (1-\lambda^t)\ell_m)$. A major problem is repaired at cost c_t with probability λ^t and remains unrepaired with probability $1-\lambda^t$. Thus, the social loss (including the treatment cost) associated with a major problem is $q(\lambda^t c_t + (1-\lambda^t)\ell_M)$. Therefore, the social welfare level achieved in the class of inefficient equilibria in Proposition 2 is given by

$$\tilde{W}_{LV} = -(1-q)\sigma^t(\lambda^t c_t + (1-\lambda^t)\ell_m) - q(\lambda^t c_t + (1-\lambda^t)\ell_M) = -q(\ell_M - \ell_m), \tag{13}$$

which is also larger than the welfare $\tilde{W}_L$ given in (9).

In Proposition 2, for $P_M^t \in [\ell_m + c_t, \ell_M]$, the consumer's acceptance rate $\lambda^t \in [\frac{\ell_m}{\ell_M - c_t}, 1]$ is always larger than the equilibrium acceptance rate $\frac{\ell_m}{\ell_M}$ in the setting with just liability. The social benefits from the increased probability of a major problem being resolved dominate the social loss associated with overtreatment. Therefore, imposing verifiability is socially beneficial. We illustrate this insight with a numerical example.

Numerical Example. Suppose $(\ell_m, \ell_M) = (1, 5)$ and $q = 0.4$, which implies $\bar{\ell} = 2.6$. Let $c = 3$ and $\alpha = 1.2$ such that assumptions (1) and (2) hold.

In the setting with just liability, $P^L = P^H = (\ell_m, \ell_M) = (1, 5)$ in the unique equilibrium. Following such prices, $\sigma = 0$ and $\lambda = 20\%$. The expected profits of the two types are $\tilde{\Pi}^L = 0.76$ and $\tilde{\Pi}^H = 0.712$. The *ex ante* welfare level (as a function of x) is equal to $\tilde{W}_L = -1.888 + 0.048x$.

In the setting with both liability and verifiability, in the efficient equilibrium $P^L = (\ell_m, \ell_m + c) = (1, 4)$ and $P^H = (\ell_m, \ell_m + \alpha c) = (1, 4.6)$. Following such prices, $\sigma^L = \sigma^H = 0$ and $\lambda = 1$. The expected profits of the two types are $\tilde{\Pi}^L = \tilde{\Pi}^H = 1$. The welfare level achieved in this equilibrium is $\tilde{W}_{LV} = -1.44 + 0.24x > \tilde{W}_L$ for all x. Among the inefficient equilibria, the minimum welfare level is achieved with price $P^L = P^H = (\ell_m, \ell_M) = (1, 5)$. In this equilibrium, $\sigma^L = \sigma^H = 0$, $\lambda^L = 50\%$, $\lambda^H = 71.4\%$, $\tilde{W}_{LV} = -1.6$, which is also larger than $\tilde{W}_L$.

4 Unobservable Expert Types

In this section, we examine whether verifiability is still socially beneficial when expert types are unobservable to the consumer. In contrast to the case of observable expert types, the realization of $t \in \{L, H\}$ is now the expert's private information, and *ex ante* the consumer is only aware of the prior distribution $\Pr\{t = L\} = 1 - \Pr\{t = H\} = x$. Therefore, the prices posted by the expert naturally have a signaling role and convey information about the expert's private treatment costs. In the timeline described in Section 2, after observing the posted price P, the consumer updates her belief, $\mu(t \mid P)$ for $t \in \{H, L\}$, about the probability that the expert is of type t before she visits the expert with her problem.

A profile $\{P^L, P^H; \sigma^L, \sigma^H; \lambda; \mu(t \mid P)\}$ constitutes a perfect Bayesian equilibrium if it satisfies the following conditions:

1. Given $\{P^L, P^H\}$ and the consumer's updated belief $\mu(t \mid P)$ about the expert's type, an expert's recommendation strategy σ^t, $t \in \{L, H\}$ and the consumer's acceptance policy λ are mutually best responses.

2. On the equilibrium path, the consumer's updated belief $\mu(t \mid P)$ is consistent with the expert's choices of prices $\{P^L, P^H\}$.

3. An expert's choice of prices maximizes his expected profits, anticipating the consumer's updated belief $\mu(t \mid P)$ and subsequent (σ^t, λ).

Similar to Section 3, we will solve the game in the setting with just liability and in the setting with both liability and verifiability in sequence. While the analysis for the former setting is simple, the analysis for the latter is more complex due to the existence of multiple equilibria.

4.1 Equilibrium under Liability

Recall from Section 3.1 that, when expert types are observable, the equilibrium in the recommendation subgame following a given price list is the same for the two types despite their cost heterogeneity. Thus, neither type has an incentive to separate himself through signaling when treatment costs are the expert's private information. In the following proposition, we show that the equilibrium outcome characterized in Proposition 1 is indeed supported as the *unique* price-pooling perfect Bayesian equilibrium when expert types are unobservable.

Proposition 3 *Under the assumption of liability, when expert types are unobservable, there is a unique price-pooling equilibrium in which both types post the price list $P_p = (P_m, P_M) = (\ell_m, \ell_M)$. The belief system, the two types' recommendation policies, and the consumer's acceptance policy are respectively*

$$\mu(H \mid P) = \begin{cases} 1 - x & \textit{if } P = P_p \\ 0 & \textit{otherwise} \end{cases}, \qquad \sigma^H = \sigma^L = 0, \qquad \lambda = \frac{\ell_m}{\ell_M}. \tag{14}$$

Proposition 3 implies that, in the setting with just liability, asymmetric information about the expert's treatment costs has no impact on the equilibrium outcome. The reason for this absence of impact is that the expert does not have to actually perform T_M when he recommends fixing the consumer's problem at price $R = P_M$. As a result, at stages 3 and 4, the consumer's acceptance policy in a price-pooling equilibrium is always determined by $\lambda P_M = P_m$, irrespective of her belief about the expert type. Since the consumer's belief does not change her acceptance rate of $R = P_M$, any price list with $P_M < \ell_M$ cannot be supported in equilibrium because the expert always has an incentive to deviate to $P'_M = \ell_M$, which brings a higher expected payoff even if he is perceived as a low-cost type.

Since the same equilibrium outcome in Proposition 1 is supported as the unique price-pooling equilibrium, the social welfare achieved under unobservable expert types is the same as that given in (9). The equilibrium outcome is inefficient, although both expert types make honest recommendations, since the major problem is unresolved due to the consumer rejecting $R = P_M$ with probability $1 - \lambda = 1 - \frac{\ell_m}{\ell_M}$.

4.2 Equilibria under Liability and Verifiability

When both liability and verifiability hold, overtreatment occurs if, in equilibrium, an expert recommends T_M with positive probability when $\theta = m$; that is, $\sigma^t > 0$ for any $t \in \{L, H\}$. We first argue that there exists no separating equilibrium where different expert types post different prices, and then focus on the analysis of price-pooling equilibria.

When verifiability holds as well as liability, for a given price list, the consumer accepts $R = T_M$ with a larger probability if she believes the expert is a high-cost rather than a low-cost type. This higher acceptance rate is beneficial for the expert. In a separating equilibrium with $P^H \neq P^L$, the low-cost type has an incentive to mimic the high-cost type in order to attain the higher profit associated with the higher acceptance rate. To prevent mimicking, the high-cost type can either keep P_M low while keeping $P_m = \ell_m$, in order to lower the profit margin from providing T_M, or he can choose $P_m < \ell_m$ while keeping $P_M = \ell_M$, to lower the consumer's acceptance rate. However, for any price list that prevents the low-cost type from mimicking, the high-cost type's profit is so low that he is always better off choosing $P' = (\ell_m, \ell_M)$ and being perceived as a low-cost type instead. Thus, no separating prices can be supported in a perfect Bayesian equilibrium.

Lemma 1 *Suppose both liability and verifiability hold and expert types are unobservable. There exists no separating equilibrium in which the two expert types post different prices.*

4.2.1 Price-pooling equilibria

In a price-pooling equilibrium, the two expert types post the same price list $P_p = P^H = P^L = (P_m, P_M)$. Since no information is revealed through the posted prices, the consumer's beliefs remain the same as her priors on observing P_p, $\mu(H \mid P_p) = 1 - x$. In the analysis, we adopt the most unfavorable off-equilibrium path belief, $\mu(H \mid P) = 0$ for $P \neq P_p$, to check the two types' deviation incentives. Since the high-cost and low-cost types can pocket maximal deviation profits, $\ell_m - \frac{\ell_m}{\ell_M - c}(\alpha - 1)cq$ and ℓ_m respectively, by posting $P' = (\ell_m, \ell_M)$ and inducing belief $\mu(H \mid P') = 0$, and the consumer acceptance rate $\lambda = \frac{\ell_m}{\ell_M - c}$, price list P_p can be supported in a price-pooling equilibrium *if and only if*

$$\Pi^H(P_p) \geq \ell_m - \frac{\ell_m}{\ell_M - c}(\alpha - 1)cq, \qquad \Pi^L(P_p) \geq \ell_m. \tag{15}$$

Using (15) and applying the intuitive criterion to rule out equilibria that are supported through implausible off-equilibrium path beliefs, we can characterize the complete set of price-pooling equilibria. We show that the magnitude of x, the probability that the expert is of low-cost type, and the magnitude of q, the probability that the consumer has a major problem, affect the existence of different categories of equilibria. After characterizing the complete set of price-pooling equilibria that survive the intuitive criterion, we also apply the principle of payoff dominance whenever possible, in order to select the most plausible equilibria from the expert's viewpoint.

As a first step in the analysis, it is natural to wonder whether the efficient equilibrium characterized in Proposition 2 under observable expert types can still be supported as an equilibrium when the types are unobservable. For $\sigma^L = \sigma^H = 0$ and $\lambda = 1$ to be part of a perfect Bayesian equilibrium, the price list must satisfy $(P_m, P_M) \in [(\alpha - 1)c, \ell_m] \times [\alpha c, P_m + c]$; otherwise, the low-cost type would have an incentive to overtreat. Although the consumer accepts $R = T_M$ with probability one, the price for a major treatment P_M is so low that the first part of condition

(15) is always violated: the high-cost type has an incentive to deviate to price list $P' = (\ell_m, \ell_M)$, even though he is perceived as a low-cost type for such prices, and the consumer accepts $R = T_M$ with a smaller probability. Thus, we conclude that, unlike in the scenario of observable types, the efficient outcome cannot be supported in equilibrium under unobservable expert types.

Lemma 2 *Suppose both liability and verifiability hold and expert types are unobservable. There exists no price-pooling equilibrium with $\sigma^L = \sigma^H = 0$ and $\lambda = 1$.*

To characterize the complete set of price-pooling equilibria, we provide a useful observation in the next lemma showing that there exists no pooling equilibrium with $\sigma^L \in (0,1)$. For such an equilibrium to exist, the consumer's acceptance rate of $R = T_M$ must also be interior, $\lambda \in (0,1)$, to make the low-cost type indifferent between $R = T_m$ and $R = T_M$ when $\theta = m$. This in turn leads to the unique ratio of overtreatment with $\sigma^L = \frac{q(\ell_M - P_M)}{x(1-q)(P_M - \ell_m)}$, implying $P_M < \ell_M$ for $\sigma^L \in (0,1)$. However, the high-cost type is not willing to pool at such a price list because his profit would be higher if he chose $P' = (\ell_m, \ell_M)$ and was instead perceived as a low-cost type.

Lemma 3 *Suppose both liability and verifiability hold and expert types are unobservable. There exists no price-pooling equilibrium with $\sigma^L \in (0,1)$.*

Using Lemma 3, we can divide all potential price-pooling equilibria into two categories: (i) the low-cost type who does not overtreat, $\sigma^L = 0$; and (ii) the low-cost type who always overtreats, $\sigma^L = 1$. Note that, for a pooling price list $P_p = (P_m, P_M) \in [0, \ell_m] \times [\alpha c, \ell_M]$, the low-cost type has a stronger incentive to overtreat than the high-cost type, because the former receives a larger profit margin from overtreating ($P_M - c > P_M - \alpha c$). If the high-cost type overtreats with a positive probability, the low-cost type will overtreat with probability one. Thus, in the first category of equilibria, $\sigma^H = 0$ must hold; in the second category, either $\sigma^H = 0$ or $\sigma^H \in (0,1)$ may occur depending on the parameter sets.

Price-pooling Equilibria with $\sigma^L = 0$. The next proposition characterizes the unique price-pooling equilibrium in which the low-cost type does not overtreat.

Proposition 4 (Pooling Equilibrium with $\sigma^L = 0$) *Suppose both liability and verifiability hold and expert types are unobservable. There exists a unique price-pooling equilibrium with $\sigma^L = 0$*

that survives the intuitive criterion. In equilibrium, both expert types post the price list $P_p = (\ell_m, \ell_M)$; the expert's recommendation policies and the consumer's acceptance policy are respectively $\sigma^H = \sigma^L = 0$ and $\lambda = \frac{\ell_m}{\ell_M - c}$. The two types' expected profits from this equilibrium are respectively $\hat{\Pi}^L = \ell_m$ and $\hat{\Pi}^H = \ell_m(1 - \frac{q(\alpha-1)c}{\ell_M - c}) < \ell_m$.

In the equilibrium identified in Proposition 4, the prices posted by the expert lead to honest recommendations in stage 3. The outcome is nevertheless inefficient because a major problem remains unresolved with a positive probability equal to $1 - \frac{\ell_m}{\ell_M - c}$. Compared with the outcome under observable types in Proposition 2, the high-cost type is worse off because his recommendation of $R = T_M$ is now accepted with a lower probability ($\lambda = \frac{\ell_m}{\ell_M - c} < \frac{\ell_m}{\ell_M - \alpha c}$). The low-cost type's expected profit is the same because he always has an option to deviate to an alternative price list, as characterized in Proposition 2, being perceived as a low-cost type and securing a profit equal to ℓ_m.

Price-pooling Equilibria with $\sigma^L = 1$. Note that there exists no equilibrium with $\sigma^L = \sigma^H = 1$. For both expert types to overtreat with probability one, any positive acceptance rate of the consumer requires $P_M \leq \bar{\ell}$, which implies negative profit for both expert types in providing T_M. Thus, in a price-pooling equilibrium with $\sigma^L = 1$, it holds that $\sigma^H \in [0, 1)$. It follows that there are four combinations to consider that could characterize the full set of equilibria: 1) $\sigma^H \in (0, 1)$ and $\lambda \in (0, 1)$; 2) $\sigma^H \in (0, 1)$ and $\lambda = 1$; 3) $\sigma^H = 0$ and $\lambda \in (0, 1)$; 4) $\sigma^H = 0$ and $\lambda = 1$.

In the proof of Proposition 5 in the Appendix, we analyze these four combinations in sequence and derive the complete set of equilibria with $\sigma^L = 1$ that survives the intuitive criterion. Afterward, we apply the principle of payoff dominance to select the most plausible equilibria from the expert's viewpoint. Proposition 5 below summarizes these payoff-dominant equilibria and the conditions for their existence.

Define $\underline{x} \equiv \frac{q}{1-q} \frac{\ell_M - \ell_m - \alpha c}{\alpha c}$ and $\bar{x} \equiv \frac{q}{1-q} \frac{\ell_M - \ell_m - \alpha c + \ell_m(\alpha-1)c/(\ell_M - c)}{\alpha c - \ell_m(\alpha-1)c/(\ell_M - c)}$ where $0 < \underline{x} < \bar{x} < 1$. Assumption (1) implies that $q < \frac{c - \ell_m}{\ell_M - \ell_m} \equiv \tilde{q}$.

Proposition 5 (Pooling equilibria with $\sigma^L = 1$) *Suppose both liability and verifiability hold and expert types are unobservable.*

(1) When $x < \underline{x}$, there exist multiple price-pooling equilibria with $\sigma^L = 1$ that survive the intuitive criterion. In the payoff-dominant equilibrium, $P_p = (\ell_m, \ell_m + \alpha c)$; the expert's recommendation policies and the consumer's acceptance policy are respectively $\sigma^L = 1$, $\sigma^H = 0$, and $\lambda = 1$. The expert's expected profits are $\hat{\Pi}^H = \ell_m$ and $\hat{\Pi}^L = \ell_m + \alpha c - c$.[13]

(2) When $x \in [\underline{x}, \bar{x}]$ and $q \leq \min\{1 - \frac{\ell_M - \ell_m - c}{\ell_M - c}\frac{\ell_M - \alpha c}{\ell_m}, \tilde{q}\}$, there exists a continuum of price-pooling equilibria that survive the intuitive criterion. In the payoff-dominant equilibrium, $P_p = (\ell_m, \hat{P}_M)$ with $\hat{P}_M \equiv \min\{P_*, \frac{q\ell_M + x(1-q)\ell_m}{q + x(1-q)}\}$ and P_* is the solution to

$$\frac{q(P_* - \alpha c) + (1-q)\ell_m}{\ell_M - \alpha c}(\ell_M - c) = P_* - c.$$

The expert's recommendation policies and the consumer's acceptance rate are $\sigma^L = 1$, $\sigma^H = 0$, and $\lambda = 1$. The expert's expected profits are $\hat{\Pi}^H = q(\hat{P}_M - \alpha c) + (1-q)\ell_m$ and $\hat{\Pi}^L = \hat{P}_M - c$.

(3) When $x \in [\underline{x}, \bar{x}]$ and $q > \min\{1 - \frac{\ell_M - \ell_m - c}{\ell_M - c}\frac{\ell_M - \alpha c}{\ell_m}, \tilde{q}\}$, or when $x > \bar{x}$, there exists no price-pooling equilibrium with $\sigma^L = 1$.

In the equilibria characterized in Proposition 5, different prices are supported depending on the parameters x and q. However, the expert's recommendation policies and the consumer's acceptance policy are identically given by $\sigma^L = 1$, $\sigma^H = 0$, and $\lambda = 1$. Thus, the low-cost type overtreats the consumer with probability one and the high-cost type always provides honest recommendations, while the consumer accepts a recommendation of $R = T_M$ with probability one. The high-cost type overtreating with an interior probability, $\sigma^H \in (0, 1)$, can also occur in equilibrium when $x < \underline{x}$, because with $P_M = P_m + \alpha c$ the high-cost type receives the same profit when providing T_m and T_M for $\theta = m$. Such equilibria are eliminated by the tie-breaking rule that the expert will choose the lowest $\sigma = 0$ if he is indifferent between multiple recommendation policies.

[13] When x is small, there also exists a semi-pooling equilibrium in which the low-cost type posts price list $P_p = (\ell_m, \ell_m + \alpha c)$, while the high-cost type pools at P_p with a positive probability and separates himself through $P^H = (\ell_m, \ell_M)$ with the complementary probability. In equilibrium, $\sigma^L = 1$, $\sigma^H = 0$, and the expert's expected profits are also $\Pi^H = \ell_m$ and $\Pi^L = \ell_m + \alpha c - c$.

In part (2) of Proposition 5, $\ell_m + c \leq \hat{P}_M < \ell_m + \alpha c$, meaning that the low-cost type chooses $\sigma^L = 1$ and the high-cost type chooses $\sigma^H = 0$. The price list $\hat{P}_M$ ensures that the consumer is better off accepting than rejecting $R = T_M$. $\hat{P}_M = P_*$ imposes an upper bound on the low-cost type's equilibrium profit. Any price list with $P_M > P_*$ that brings the high-cost type a profit Π^H fails the intuitive criterion: the high-cost type can instead choose $P' = (\Pi^H + \epsilon, \ell_M)$ in order to increase his profit, while such a price is not profitable for the low-cost type. For $P_M \leq P_*$, on the other hand, the low-cost type's profit is so low that any promising deviation for the high-cost type is also profitable for the low-cost type.

In a price-pooling equilibrium with $\sigma_L = 1$, the low-cost type always recommends T_M when $\theta = m$, but the price P_M is sufficiently low that the consumer always accepts $R = T_M$. Inefficiency now comes solely from overtreatment costs rather than an unrepaired major problem, as in Proposition 4.

4.3 Benefits of Verifiability

To evaluate the role of verifiability under unobservable expert types, we need to compare the welfare attained in the setting with just liability with that in the setting with both liability and verifiability. Since multiple equilibria coexist in the latter setting, we first collect the payoff-dominant equilibrium among the ones characterized in Propositions 4 and 5 in the following corollary. In doing so, we exploit the fact that the equilibrium in Proposition 4 always exists, while the existence of the equilibria in Proposition 5 depends on the magnitude of x and/or q.

Corollary 2 *Suppose both liability and verifiability hold and expert types are unobservable. The unique payoff-dominant price-pooling equilibrium is as follows:*

(1) For $x < \underline{x}$, $P_p = (\ell_m, \ell_m + \alpha c)$, following which $\sigma^L = 1$, $\sigma^H = 0$, and $\lambda = 1$. The expert's expected profits are $\hat{\Pi}^H = \ell_m$ and $\hat{\Pi}^L = \ell_m + \alpha c - c$.

(2) For $x \in [\underline{x}, \bar{x}]$, when $q \leq \min\{1 - \frac{\ell_M - \ell_m - c}{\ell_M - c}\frac{\ell_M - \alpha c}{\ell_m}, \tilde{q}\}$, $P_p = (\ell_m, \hat{P}_M)$, following which $\sigma^L = 1$, $\sigma^H = 0$, and $\lambda = 1$. The expert's expected profits are $\hat{\Pi}^H = q(\hat{P}_M - \alpha c) + (1-q)\ell_m$ and $\hat{\Pi}^L = \hat{P}_M - c$.

(3) For $x > \bar{x}$ or $x \in [\underline{x}, \bar{x}]$ and $q \in (\min\{1 - \frac{\ell_M - \ell_m - c}{\ell_M - c}\frac{\ell_M - \alpha c}{\ell_m}, \tilde{q}\}, \tilde{q})$, $P_p = (\ell_m, \ell_M)$, following

which $\sigma^L = \sigma^H = 0$, $\lambda = \frac{\ell_m}{\ell_M - c}$. *The expert's expected profits are* $\hat{\Pi}^H = \ell_m(1 - \frac{q(\alpha-1)c}{\ell_M - c})$ *and* $\hat{\Pi}^L = \ell_m$.

In parts (1) and (2) of Corollary 2, since the consumer accepts $R = T_M$ with probability one, the consumer's problem is always resolved. A major problem is repaired at an expected cost of $xc + (1-x)\alpha c$, while a minor problem is repaired at an expected cost of xc. Thus, there is a social waste in that a minor problem is repaired through T_M with a positive probability. The social welfare from this part of the equilibrium is

$$\hat{W}_{LV} = -q\left(xc + (1-x)\alpha c\right) - (1-q)xc = -(xc + q(1-x)\alpha c) \equiv \Delta_1. \tag{16}$$

In part (3) of Corollary 2, a minor problem is always repaired, while a major problem is either repaired at an expected cost of $xc + (1-x)\alpha c$, which occurs with probability $\lambda = \frac{\ell_m}{\ell_M - c}$, or remains unrepaired with probability $1 - \lambda$. In the latter case, no treatment cost is incurred but the consumer suffers a loss ℓ_M. Thus, the social welfare attained in part (3) of the equilibrium is given by

$$\begin{aligned}\hat{W}_{LV} &= -q\frac{\ell_m}{\ell_M - c}\left(xc + (1-x)\alpha c\right) - q\frac{\ell_M - c - \ell_m}{\ell_M - c}\ell_M \\ &= -q(\ell_M - \ell_m) - q\frac{\ell_m}{\ell_M - c}(1-x)(\alpha - 1)c \equiv \Delta_2. \end{aligned}\tag{17}$$

In the setting with just liability, the equilibrium social welfare level is given by $\tilde{W}_L$ in (9). It is straightforward to get $\tilde{W}_L < \Delta_2 < \Delta_1$. Moreover, the incremental welfare from imposing verifiability

$$\Delta_1 - \tilde{W}_L = q(\ell_M - \ell_m) - \frac{\ell_M - \ell_m}{\ell_M}\alpha c q + \frac{(\alpha q - 1)\ell_M - (\alpha - 1)q\ell_m}{\ell_M}cx$$

decreases in x, and

$$\Delta_2 - \tilde{W}_L = \frac{q\ell_m c}{\ell_M - c}\frac{\ell_M - \alpha c + xc(\alpha - 1)}{\ell_M}$$

increases in x. We conclude that:

Corollary 3 *Under unobservable expert types, imposing verifiability on top of liability increases social welfare. Moreover, the incremental benefits of verifiability first decrease and then increase in x.*

When x is sufficiently small or when x is intermediate with a sufficiently small q, the payoff-dominant equilibrium in the setting with both liability and verifiability is part (1) and (2) in Corollary 2. A low-cost type always overtreats, a high-cost type never overtreats, and the consumer's problem is always repaired. The social benefits from always repairing the major problem dominate the waste from overtreatment, so social welfare is higher when verifiability holds.

When x is high or intermediate with a relatively large q, the equilibrium is given in part (3) of Corollary 2. No overtreatment occurs in equilibrium. Since a recommendation of T_M is rejected with a positive probability, the social welfare loss comes solely from a possibly unrepaired major problem. However, compared with the setting with just liability, the consumer accepts $R = T_M$ with a larger probability, and thus the social welfare is higher with verifiability as well.

In summary, under unobservable expert types, although the efficient outcome is no longer supported as an equilibrium in the setting with both liability and verifiability, the benefits from the increased probability of a major problem being repaired dominate the social waste from overtreatment. Therefore, similar to the scenario under observable types, imposing verifiability on top of liability increases social welfare.

In parts (1) and (2) of Corollary 2 where $\sigma^L = 1$, $\sigma^H = 0$, and $\lambda = 1$, the consumer's acceptance rate of T_M is not affected by x, but the treatment cost associated with overtreatment decreases with x because a low-cost type performs a major treatment at a lower cost. Meanwhile, an increase in x increases the social waste from the low-cost type's overtreatment. The increased social waste from overtreatment dominates the decreased average treatment cost. Thus, Δ_1 decreases with x. In addition, $\tilde{W}_L$ increases with x due to the lower average cost of major treatment. Therefore, the incremental benefit of imposing verifiability on top of liability, $\Delta_1 - \tilde{W}_L$, decreases with x.

On the other hand, in part (3) of Corollary 2 where $\sigma^L = \sigma^H = 0$ and $\lambda = \frac{\ell_m}{\ell_M - c}$, an increase in x reduces the average cost of repairing a major problem. Moreover, the acceptance rate $\lambda = \frac{\ell_m}{\ell_M - c}$

is higher than that in the setting with just liability, which is $\lambda = \frac{\ell_m}{\ell_M}$, and both rates are unaffected by x. Therefore, the incremental benefit of imposing verifiability on top of liability in this case, $\Delta_2 - \tilde{W}_L$, increases with x.

Recall that, under observable expert types, social welfare in the setting with both liability and verifiability for the inefficient equilibria is given in (13). When this equilibrium is played, $\tilde{W}_{LV} < \hat{W}_{LV} = \Delta_1$ implies that the existence of asymmetric information may increase social welfare. Under unobservable expert types, when the expert is unlikely to be low cost (x sufficiently low), the overtreating incentive of the high-cost type becomes important. The consumer's uncertainty about the expert's treatment costs drives down the P_M that can be supported in equilibrium, which in turn leads to the consumer accepting a recommendation of T_M with probability one, meaning that a major problem is always repaired. By contrast, a major problem remains unresolved with probability $1 - \frac{\ell_m}{\ell_M - c_t}$ in the inefficient equilibria in Proposition 2, and the existence of asymmetric information may increase this probability to one, consequently increasing social welfare. This finding suggests that policies aiming at improving the consumer's information about the expert's treatment costs may backfire in the regulation of the credence goods market.

Numerical Example. Now we revisit the numerical example in Section 3 where $\ell_m = 1$, $\ell_M = 5$, $c = 3$, and $\alpha = 1.2$. In the setting with both liability and verifiability, by Corollary 2, the unique payoff-dominant price-pooling equilibrium is:

(1) For $x < \frac{q}{9(1-q)}$, both types pool at $P_p = (1, 4.6)$, following which $\sigma^L = 1$, $\sigma^H = 0$, and $\lambda = 1$. The expert's expected profits are $\hat{\Pi}^H = 1$ and $\hat{\Pi}^L = 1.6$. The welfare is $\Delta_1 = -xc - q(1-x)\alpha c = -(3 - 3.6q)x - 3.6q$. Let "$E1$" denote this part of the equilibrium.

(2) For $x \in [\frac{q}{9(1-q)}, \frac{7q}{33(1-q)}]$, when $q \leq 0.3$, both types pool at $P_p = (1, \min\{\frac{31-46q}{7-10q}, \frac{5q+x(1-q)}{q+x(1-q)}\})$, following which $\sigma^L = 1$, $\sigma^H = 0$, and $\lambda = 1$. The expert's expected profits are $\hat{\Pi}^H = \min\{\frac{7-11.2q}{7-10q}, \frac{1.4q^2-2.6x(1-q)q}{q+x(1-q)} + (1-q)\} \in [0.91, 1]$ and $\hat{\Pi}^L = \min\{\frac{10-16q}{7-10q}, \frac{2q-2x(1-q)}{q+x(1-q)}\} \in [1.3, 1.42]$. The welfare level is also given by Δ_1. Let "$E2$" denote this part of the equilibrium.

(3) For $x > \frac{7q}{33(1-q)}$, or $x \in [\frac{q}{9(1-q)}, \frac{7q}{33(1-q)}]$, and $q > 0.3$, $P_p = (1, 5)$, following which $\sigma^L = \sigma^H = 0$, $\lambda = 50\%$. The expert's expected profits are $\hat{\Pi}^H = 0.88$ and $\hat{\Pi}^L = 1$. The welfare

is $\Delta_2 = 0.3qx - 4.3q$. Let "$E3$" denote this part of the equilibrium.

The left panel of Figure 1 demonstrates the three parts of the price-pooling equilibrium in the "$x - q$" space. Under Proposition 3, the social welfare in the setting with just liability is the same as that with observable types, and thus $\tilde{W}_L = -1.888 + 0.048x$. The right panel of Figure 1 illustrates how the incremental benefits of imposing verifiability on top of liability, $\Delta W \equiv \hat{W}_{LV} - \tilde{W}_L$, vary with x for $q = 0.1$ and $q = 0.4$ respectively. For both values of q, ΔW first decreases and then increases with x.

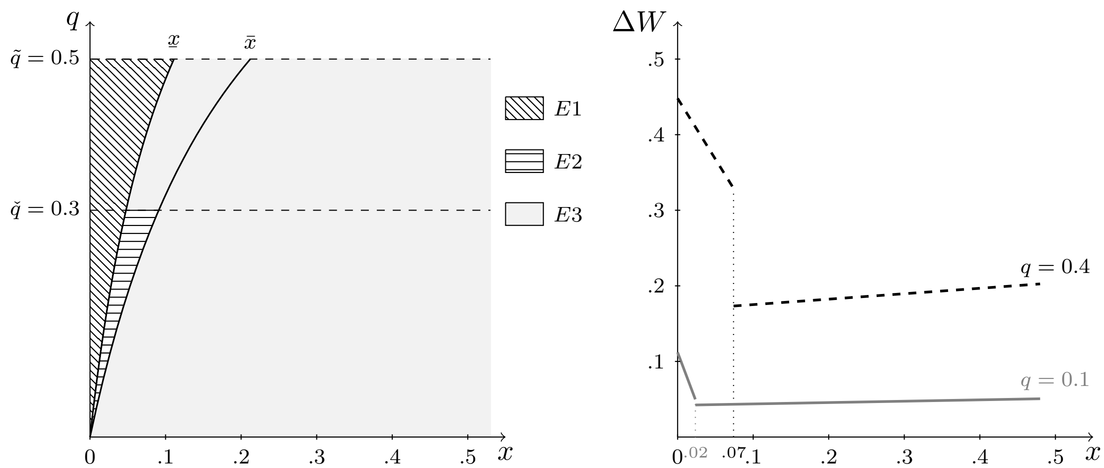

Figure 1: The Price-Pooling Equilibrium and Incremental Benefits of Verifiability for $\ell_m = 1$, $\ell_M = 5$, $c = 3$ and $\alpha = 1.2$.

5 Discussions

Our main model has normalized the treatment costs for a minor problem to zero and considers a monopolist expert. In this section we relax these assumptions and show that imposing verifiability on top of liability can still enhance welfare. For these discussions, we assume the types of the expert(s) are observable.

Heterogeneous Costs for Minor Treatment Suppose the two expert types also have heterogeneous costs for minor treatment, $k_t = k$ for the low-cost type and $k_t = \beta k$ with $\beta > 1$ for the high-cost type, with $\ell_m > \beta k$. In the setting with just liability, the equilibrium prices and the expert's recommendation strategy remain the same as those in Proposition 1, while the consumer's acceptance policy now changes to $\check{\lambda}^t = (\ell_m - k_t)/(\ell_M - k_t)$, $t \in \{L, H\}$. In the setting with both liability and verifiability, both classes of equilibria in Proposition 2 hold with some adaptations. Consider the inefficient equilibria. The prices change to $(P_m^t, P_M^t) \in \{\ell_m\} \times (\ell_m + c_t - k_t, \ell_M]$. While the expert's recommendation policy remains the same as that in equation (11), the consumer's acceptance policy becomes $\check{\lambda}^t = (\ell_m - k_t)/(P_M^t - c_t)$. The consumer acceptance rate is higher when verifiability holds as well. Thus, imposing verifiability on top of liability also enhances social welfare with the presence of heterogeneous costs for minor treatment.[14]

Competitive Expert Market Suppose there are two homogeneous experts with identical treatment costs (0 for a minor treatment and c for a major treatment) who compete by simultaneously setting prices (P_m^i, P_M^i), $i = \{A, B\}$. The consumer decides which expert to visit after observing the prices. We assume that the game ends if the consumer rejects an expert's recommendation.[15] We focus on sensible prices with $\ell_M \geq P_M^i \geq c$ and $\ell_m \geq P_m^i \geq 0$.

Proposition 6 *Suppose the expert market is competitive. (1) In the setting with just liability, the unique equilibrium has* $(P_m^i, P_M^i) = (0, \ell_M)$*, with* $\sigma^i = \lambda^i = 0$ *for* $i = \{A, B\}$*. (2) In the setting with both liability and verifiability, the unique equilibrium has* $(P_m^i, P_M^i) = (0, c)$ *with* $\sigma^i = 0$ *and* $\lambda^i = 1$*. Thus, imposing verifiability on top of liability improves social welfare.*

In the setting with just liability, the experts have incentives to overcharge the consumer since $P_M^i > P_m^i$ always holds. The equilibrium outcome is inefficient because the consumer's major problem is not resolved. When verifiability holds as well, the experts always provide honest recommendations which are always accepted by the consumer, and the equilibrium outcome is socially efficient. Thus, competition between experts cannot correct the experts' cheating incentives when only liability holds; however, it can fully restore market efficiency when verifiability holds as well.

[14] More details can be found in Remark 1 and its proof in the Appendix.

[15] One potential complication with the presence of multiple experts is that the consumer may visit a second expert after receiving a recommendation from a first expert. We implicitly assume that the consumer cannot gain by visiting a second expert, possibly because the switch cost is high or the consumer expects to receive a similar recommendation because the two experts adopt identical strategies.

6 Conclusion

We study a credence goods market in which the expert may have a high or low cost in repairing a major problem and where it is more socially valuable to repair a major problem than a minor problem. When the expert is liable for repairing the consumer's problem (that is, liability holds), the expert may cheat through overcharging. When the type of treatment that the consumer receives is also costlessly verifiable (that is, verifiability also holds), the expert may cheat through overtreatment. We characterize the market equilibria in these two sets of institutions for observable and unobservable expert types. With just liability, an inefficiency arises because not all major problems are resolved in equilibrium. With both liability and verifiability, another inefficiency arises because minor problems are sometimes fixed through costly major treatments. We show that imposing verifiability on top of liability always increases social welfare. Adding verifiability improves the probability with which a major problem is repaired. The benefits from the increased probability of a major problem being repaired dominate the social waste from overtreatment. We also demonstrate how the incremental benefit of imposing verifiability varies with the probability that the expert is a low-cost type.

Appendix

This appendix contains the proofs of Propositions 2–6, Lemmas 1–3, and Remark 1. The proof of Proposition 1 is substantiated in the main text.

Proof of Proposition 2. We will first characterize the equilibrium of the recommendation subgame for any given price list, and then compare the expert's profits from posting different prices and solve for the optimal price list in the first stage. For the first part, we divide all feasible price lists $(P_m^t, P_M^t) \in [0, \ell_m] \times [c_t, \ell_M]$ into four cases $P_M^t \in [c_t, P_m^t + c_t)$, $P_M^t = P_m^t + c_t$, $P_M^t \in (P_m^t + c_t, \ell_M)$, and $P_M^t = \ell_M$, and solve for the expert's recommendation strategy σ^t and the consumer's acceptance strategy λ^t that are mutually best responses in each case.

1. For any given price $(P_m^t, P_M^t) \in [0, \ell_m] \times [c_t, P_m^t + c_t)$, the expert would honestly recommend T_m when $\theta = m$ since $P_M^t - c_t < P_m^t$, and the consumer always accepts a recommendation of T_M. Thus there

is a unique equilibrium in the recommendation subgame with

$$\sigma^t = 0, \quad \lambda^t = 1; \qquad \Pi^t(P^t) = q(P_M^t - c_t) + (1-q)P_m^t < P_m^t.$$

2. For any given price $(P_m^t, P_M^t) \in [0, \ell_m] \times (P_m^t + c_t, \ell_M)$, we show that $\lambda^t \in (0,1)$ must hold. If $\lambda^t = 1$, the expert would optimally set $\sigma^t = 1$, implying that $\lambda^t = 1$ cannot be a best response since $-P_M^t < -\bar{\ell}$. If $\lambda^t = 0$, the expert would optimally set $\sigma^t = 0$ (unless $P_m^t = 0$ which is obviously dominated by a positive P_m^t for the expert). This in turn implies that the consumer should accept $R = T_M$ because $-P_M^t > -\ell_M$, which is a contradiction. Therefore, the consumer must have an interior acceptance policy $\lambda^t \in (0,1)$ in the recommendation subgame. In equilibrium, the expert's recommendation policy σ^t makes the consumer indifferent between accepting and rejecting a recommendation of T_M:

$$-P_M^t = \frac{q}{q + (1-q)\sigma^t}(-\ell_M) + \frac{(1-q)\sigma^t}{q + (1-q)\sigma^t}(-\ell_m). \tag{18}$$

Meanwhile, the consumer's acceptance policy λ^t makes the expert indifferent between offering T_m and T_M when $\theta = m$:

$$P_m^t = \lambda^t(P_M^t - c_t).$$

Therefore, given $(P_m^t, P_M^t) \in [0, \ell_m] \times (P_m^t + c_t, \ell_M)$, there is a unique equilibrium in the recommendation subgame in which the equilibrium strategies and the expert's expected profits are respectively:

$$\sigma^t = \frac{q(\ell_M - P_M^t)}{(1-q)(P_M^t - \ell_m)}, \quad \lambda^t = \frac{P_m^t}{P_M^t - c_t}; \qquad \Pi^t(P^t) = P_m^t.$$

3. For any given price $(P_m^t, P_M^t) \in [0, \ell_m] \times \{P_m^t + c_t\}$, $\lambda^t < 1$ cannot be a part of an equilibrium because $\sigma^t = 0$ is a best response which in turn induces $\lambda^t = 1$ instead. Therefore, in equilibrium $\lambda^t = 1$ must hold and it follows that

$$-P_M^t \geq \frac{q}{q + (1-q)\sigma^t}(-\ell_M) + \frac{(1-q)\sigma^t}{q + (1-q)\sigma^t}(-\ell_m). \tag{19}$$

Since $P_M^t - c_t = P_m^t$, any $\sigma^t \in [0, \min\{\frac{q(\ell_M - P_M^t)}{(1-q)(P_M^t - \ell_m)}, 1\}]$ brings the expert the same expected profit and forms a best response to $\lambda^t = 1$. Applying the tie-breaking rule that when the expert is indifferent between multiple σ^t, he chooses the smallest one so that he makes honest recommendations with the largest probability, we arrive at the unique equilibrium of the recommendation subgame with

$$\sigma^t = 0, \qquad \lambda^t = 1; \qquad \Pi^t(P^t) = P^t_m.$$

4. For any given price $(P^t_m, P^t_M) \in [0, \ell_m] \times \{\ell_M\}$, $\lambda^t = 1$ cannot be a part of an equilibrium because the expert would choose $\sigma^t = 1$ in response and the consumer should not accept $R = T_M$. If $\lambda^t \in (0,1)$, (18) holds and it follows that $\sigma^t = 0$. On the other hand, if $\theta = m$, the expert offers T_m instead of T_M if

$$P^t_m \geq \lambda^t(P^t_M - c_t).$$

Thus any $\lambda^t \in [0, \frac{P^t_m}{P^t_M - c_t}]$ and $\sigma^t = 0$ form mutually best responses. Applying the tie-breaking rule that the consumer chooses the largest acceptance rate if she is indifferent between multiple rates, we arrive at the unique equilibrium of the recommendation subgame with

$$\sigma^t = 0, \quad \lambda^t = \frac{P^t_m}{P^t_M - c_t}; \qquad \Pi^t(P^t) = q(P^t_M - c_t)\frac{P^t_m}{P^t_M - c_t} + (1-q)P^t_m = P^t_m.$$

Comparing the expert's expected profits from the four cases, we arrive at the conclusion that it is optimal for an expert of type t to choose $P^t_m = \ell_m$ and $P^t_M \in [\ell_m + c_t, \ell_M]$. Note that the case of $P^t_M \in (\ell_m + c_t, \ell_M)$ and $P^t_M = \ell_M$ can be merged after applying the tie-breaking rule, we arrive at the two classes of equilibria stated in the proposition.

In both classes of equilibria, the expert's expected profits are always the same: $\tilde{\Pi}^t = P^t_m = \ell_m$. ■

Proof of Proposition 3. Consider a price-pooling equilibrium with $P^L = P^H = P_p$. The proof proceeds in two steps. We first show that there exists no price-pooling equilibrium with $P_M < \ell_M$ by showing that an expert can profitably deviate to a price list with $P_M = \ell_M$. We then analyze price-pooling equilibria with $P_M = \ell_M$ and show the unique equilibrium outcome. The equilibrium path belief is determined by the Bayes' rule: $\Pr\{H \mid P_p\} = 1 - x$. For the off-equilibrium path belief, we adopt the most unfavorable belief the consumer may have about the expert: $\Pr\{H \mid P\} = 0$ for $P \neq P_p$.

1. Consider a price-pooling equilibrium with $P_p = (P_m, P_M) \in [0, \ell_m] \times [\alpha c, \ell_M)$. It cannot be part of an equilibrium that the consumer accepts $R = P_M$ with probability one since then both expert types would offer P_M to the consumer, and the consumer should always reject such an offer. Also, it cannot be part of an equilibrium that the consumer always rejects an offer of P_M. In this case, both expert types would always recommend P_m to a consumer with $\theta = m$ (unless $P_m = 0$ which implies zero payoff for the expert and cannot be a part of an equilibrium), so the consumer should accept $R = P_M$. Thus, the consumer must

have an interior acceptance policy $\lambda \in (0,1)$ and, given σ^H and σ^L, the following indifference condition must hold:

$$\frac{q}{q+(1-q)(x\sigma^L+(1-x)\sigma^H)}(-\ell_M)+\frac{(1-q)(x\sigma^L+(1-x)\sigma^H)}{q+(1-q)(x\sigma^L+(1-x)\sigma^H)}(-\ell_m)=-P_M. \tag{20}$$

Thus $x\sigma^L+(1-x)\sigma^H \in (0,1)$, which implies that the two types cannot both choose $\sigma=0$ or $\sigma=1$. It follows that:[16]

$$\lambda P_M = P_m.$$

Therefore, in any pooling equilibrium with $P_p \in [0,\ell_m] \times [\alpha c, \ell_M)$,

$$x\sigma^L+(1-x)\sigma^H=\frac{q(\ell_M-P_M)}{(1-q)(P_M-\ell_m)}, \qquad \lambda=\frac{P_m}{P_M}.$$

With these strategies, the two types' expected profits in the proposed price-pooling equilibria are $\Pi^t(P_p) = P_m - qc_t\frac{P_m}{P_M} < \ell_m - qc_t\frac{\ell_m}{\ell_M}$.

Now consider the high-cost type's deviation incentive. Suppose the high-cost type posts price $P' = (\ell_m, \ell_M)$ instead. Given the consumer's belief $\mu(H \mid P')=0$, it is mutually best response for the expert to choose $\sigma^H=0$ and the consumer to choose $\lambda=\frac{\ell_m}{\ell_M}$ in stage 3 and 4. The high-cost type's expected profit from this deviation is $\Pi^H(P')=\ell_m - q\alpha c\frac{\ell_m}{\ell_M} > \Pi^H(P_p)$ which implies that P_p cannot be optimal for the high-cost type. Thus prices $P_p \in [0,\ell_m]\times[\alpha c,\ell_M)$ cannot be supported in equilibrium.

2. Consider a price-pooling equilibrium with $P_p=(P_m,P_M)\in[0,\ell_m]\times\{\ell_M\}$. It cannot be part of an equilibrium that the consumer always accepts an offer, so $\lambda\in[0,1)$. If $\lambda>0$, (20) must hold and it follows that $\sigma^L=\sigma^H=0$. An expert always recommends P_m to a consumer with $\theta=m$, so the consumer's acceptance rate must satisfy $P_m \geq \lambda P_M$. If $\lambda=0$, an expert would never recommend P_M to a consumer with $\theta=m$. Given that $\sigma^L=\sigma^H=0$, it is indeed optimal for the consumer to choose any $\lambda\in[0,\frac{P_m}{P_M}]$. Therefore, in a price-pooling equilibrium with $P_p\in[0,\ell_m]\times\{\ell_M\}$, it is mutually best response for an expert of type t and the consumer to choose respectively

$$\sigma^L=\sigma^H=0; \qquad \lambda\in[0,\frac{P_m}{P_M}].$$

Using the tie-breaking rule that the consumer chooses the largest one when she is indifferent between multiple acceptance rates, we have $\lambda=\frac{P_m}{P_M}$.

[16] Either at least one type chooses $\sigma^t\in(0,1)$, which leads to $\lambda P_M=P_m$ directly; or one type chooses $\sigma=0$ and the other type chooses $\sigma=1$, which requires $\lambda P_M\leq P_m$ and $\lambda P_M \geq P_m$.

Note that any P_p with $P_m < \ell_m$ cannot be supported in a price-pooling equilibrium. Suppose it is instead. The high-cost type's expected profit from such P_p is given by $\Pi^H(P_p) = P_m - q\alpha c\frac{P_m}{\ell_M} < \ell_m - q\alpha c\frac{\ell_m}{\ell_M}$. Then by deviating to $P' = (\ell_m, \ell_M)$, the consumer's belief is $\mu(H \mid P') = 0$ and it is mutually best response for the expert and the consumer to choose $\sigma = 0$ and $\lambda = \frac{\ell_m}{\ell_M}$. The high-cost type's expected profit from such deviation is $\Pi^H(P') = \ell_m - q\alpha c\frac{\ell_m}{\ell_M} > \Pi^H(P_p)$, and he has an incentive to deviate from P_p. Thus no P_p with $P_m < \ell_m$ can be supported in a price-pooling equilibrium. Therefore, we conclude that there exists a unique price-pooling equilibrium with $P_p = (P_m, P_M) = (\ell_m, \ell_M)$. ∎

Proof of Lemma 1. Suppose there exists a separating equilibrium with $P^H \neq P^L$. Since a low-cost type can always post $(P^L_m, P^L_M) \in \{\ell_m\} \times [\ell_m + c, \ell_M]$ as stated in Proposition 2 which brings profit ℓ_m when perceived as low cost, $P^L \in \{\ell_m\} \times [\ell_m + c, \ell_M]$ and $\Pi^L = \ell_m$ must hold in any separating equilibrium. Moreover, with the most unfavorable belief $\mu(H \mid P) = 0$ for $P \neq P^H$, the low-cost type has no incentive to deviate to any other price list different from P^H. When perceived as a low-cost type, the high-cost type's optimal choice is $P^d = (\ell_m, \ell_M)$, following which $\sigma^H = 0$ and $\lambda = \frac{\ell_m}{\ell_M - c}$, and $\Pi^H(P^d) = \ell_m - \frac{(\alpha-1)cq}{\ell_M - c}\ell_m$. Thus, a separating equilibrium with $P^H \neq P^L$ exists if and only if the following conditions hold

$$\Pi^L(P^L) = \ell_m \geq \Pi^L(P^H); \tag{21}$$

$$\Pi^H(P^H) \geq \max\{\Pi^H(P^L), \ell_m - \frac{(\alpha - 1)cq}{\ell_M - c}\ell_m\} \tag{22}$$

where condition (21) ensures that the low-cost type does not deviate from P^L to P^H and condition (22) ensures that the high-cost type does not deviate from P^H to P^L or the optimal deviation price P^d.

(1) Consider P^H with $P^H_M < P^H_m + c$. It follows $\sigma_H = 0$ and $\lambda = 1$ for P^H. By posting P^H, the high-cost type's expected profit is

$$\Pi^H(P^H) = q(P^H_M - \alpha c) + (1 - q)P^H_m < P^H_m - (\alpha - 1)cq \leq \ell_m - (\alpha - 1)cq < \ell_m - \frac{(\alpha - 1)cq}{\ell_M - c}\ell_m,$$

contradicting condition (22).

(2) Consider P^H with $P^H_m + c \leq P^H_M < P^H_m + \alpha c$. It follows that $\sigma^H = 0$ and $\lambda = 1$ for P^H. By posting P^H, the low-cost type will not mimic P^H if

$$\Pi^L(P^L) = \ell_m \geq \Pi^L(P^H) = P^H_M - c. \tag{23}$$

Given that $P_M^H \leq \ell_m + c$, the high-cost type's profit is

$$\Pi^H(P^H) = q(P_M^H - \alpha c) + (1-q)P_m^H \leq \ell_m - (\alpha-1)cq < \ell_m - \frac{(\alpha-1)cq}{\ell_M - c}\ell_m,$$

again contradicting condition (22).

(3) Consider P^H with $P_M^H \geq P_m^H + \alpha c$. It follows that $\sigma_H \in (0,1)$ and $\lambda = \frac{P_m^H}{P_M^H - \alpha c}$. Then $\Pi^H(P^H) = P_m^H$ and the low-cost type will not mimic P^H if

$$\Pi^L(P^L) = \ell_m \geq \Pi^L(P^H) = \frac{P_m^H}{P_M^H - \alpha c}(P_M^H - c). \tag{24}$$

However, this implies

$$\Pi^H(P^H) = P_m^H \leq \frac{P_M^H - \alpha c}{P_M^H - c}\ell_m \leq \frac{\ell_M - \alpha c}{\ell_M - c}\ell_m < \ell_m - \frac{(\alpha-1)cq}{\ell_M - c}\ell_m,$$

again contradicting condition (22).

Therefore, we conclude that there exists no separating equilibrium. ■

Proof of Lemma 2. The proof proceeds in two steps. First, we identify the intervals of prices under which $\sigma^H = \sigma^L = 0$ and $\lambda = 1$ can be supported in a price-pooling equilibrium. Second, we show the prices from the identified intervals cannot be supported in a perfect Bayesian equilibrium.

Step 1: In any pooling equilibrium with $\sigma^H = \sigma^L = 0$ and $\lambda = 1$, it must be that $(P_m, P_M) \in [(\alpha-1)c, \ell_m] \times [\alpha c, P_m + c] \equiv \Gamma_1$. Consider $(P_m, P_M) \notin \Gamma_1$. When $P_M > P_m + c$, anticipating $\lambda = 1$, the low-cost type would always recommend T_M when $\theta = m$, thus $\sigma^L = 1 \neq 0$. When $P_M < \alpha c$, the high-cost type makes negative profit from providing treatment T_M and can increase his expected profit by posting $P_M \geq \alpha c$ instead. $P_m \in [(\alpha-1)c, \ell_m]$ follows from the feasible interval for P_M.

Suppose both types have posted a price list $P_p = (P_m, P_M) \in \Gamma_1$, $\sigma^L = \sigma^H = 0$ and $\lambda = 1$ are indeed mutually best responses between the expert and the consumer at stage 3 and 4. Since the prices satisfy $P_M \geq \alpha c > c$, both expert types are willing to provide T_M at price P_M. Given the strategy of the consumer, if $\theta = m$, for the high-cost type, recommending T_M brings a payoff $P_M - \alpha c$ and recommending T_m brings a payoff P_m. Since $P_M \leq P_m + c$, it follows that $P_M - \alpha c < P_m$, and the high-cost type recommends T_m honestly, that is, $\sigma^H = 0$. For the low-cost type, if $\theta = m$, recommending T_M brings a payoff $P_M - c$ while recommending T_m brings a payoff P_m. Because $P_M - c \leq P_m$, the low-cost type has no incentive to overtreat the consumer, that is, $\sigma^L = 0$. Given the strategies of the expert, $\sigma^L = \sigma^H = 0$, if the consumer accepts a recommendation of T_M, her utility is $-P_M$, while rejecting T_M brings a utility

$-\ell_M$. Because $P_M \leq P_m + c \leq \ell_m + c < \ell_M$, accepting T_M with probability 1 is optimal for the consumer.

Step 2: we show that $(P_m, P_M) \in \Gamma_1$ cannot be supported in a price-pooling equilibrium. Suppose both types have posted such a price list, and following the price list the players choose $\sigma^L = \sigma^H = 0$ and $\lambda = 1$ on the equilibrium path. The *ex ante* expected profits of the high-cost and low-cost type are respectively:

$$\Pi^H(P_p) = q(P_M - \alpha c) + (1-q)P_m; \qquad \Pi^L(P_p) = q(P_M - c) + (1-q)P_m.$$

Note the expert's profits are increasing in the prices, $\Pi^H(P_p) \leq \ell_m - q(\alpha-1)c < \ell_m(1 - \frac{q(\alpha-1)c}{\ell_M - c})$ violating the first part of condition (15), and the high-cost type has an incentive to deviate to $P' = (\ell_m, \ell_M)$ even though he will be perceived as a low-cost type. ∎

Proof of Lemma 3. Suppose there is price-pooling equilibrium P_p with $\sigma^L \in (0,1)$. Then the low-cost type must be indifferent between offering T_m and T_M when $\theta = m$:

$$P_m = \lambda(P_M - c).$$

It follows directly that $\lambda = \frac{P_m}{P_M - c} \in (0,1)$.[17] For the high-cost type, it holds that $P_m > \lambda(P_M - \alpha c)$, thus $\sigma^H = 0$. An interior acceptance rate implies the consumer must be indifferent between accepting and rejecting a recommendation of T_M:

$$\frac{q}{x\sigma^L(1-q)+q}(-\ell_M) + \frac{x\sigma^L(1-q)}{x\sigma^L(1-q)+q}(-\ell_m) = -P_M.$$

The above indifference condition uniquely pins down $\sigma^L = \frac{q(\ell_M - P_M)}{x(1-q)(P_M - \ell_m)}$, which implies $P_M < \ell_M$ for $\sigma^L \in (0,1)$ to hold in equilibrium. The expected profits of the two types are respectively:

$$\Pi^H(P_p) = q(P_M - \alpha c)\frac{P_m}{P_M - c} + (1-q)P_m, \qquad \Pi^L(P_p) = P_m. \tag{25}$$

Given the profits in (25), the only price list that satisfies condition (15) are $P_m = \ell_m$ and $P_M = \ell_M$. However, this is contradictory to $P_M < \ell_M$. Therefore, we conclude that there exists no price-pooling equilibrium with $\sigma^L \in (0,1)$. ∎

Proof of Proposition 4. Recall that $\sigma^H = 0$ must hold in any price-pooling equilibrium with $\sigma^L = 0$.

[17] Both $\lambda = 0$ and $\lambda = 1$ can be easily ruled out. If $\lambda = 0$, $P_m = 0$ which is obviously dominated for the expert. If $\lambda = 1$, $P_m = P_M - c$. Given such strategies, $\Pi^H(P_p) = q(P_M - \alpha c) + (1-q)P_m = P_m - (\alpha-1)cq < \ell_m - (\alpha-1)cq < \ell_m - \frac{\ell_m}{\ell_M - c}(\alpha-1)cq$, violating the first part of condition (15).

And, it follows from Lemma 2 that $\lambda \in [0, 1)$. Suppose there is an equilibrium P_p with $\lambda = 0$, the consumer never accepting $R = T_M$ implies $P_M = \ell_M$. And the two types' expected profits are respectively:

$$\Pi^H(P_p) = (1-q)P_m, \qquad \Pi^L(P_p) = (1-q)P_m.$$

Since $\Pi^L(P_p) < \ell_m$ violates the second part of condition (15), there exists no price-pooling equilibrium with $\sigma^H = \sigma^L = 0$ and $\lambda = 0$.

Therefore, in any price-pooling equilibrium P_p with $\sigma^L = 0$, it must hold that $\sigma^H = 0$ and $\lambda \in (0, 1)$. This in turn implies $P_M = \ell_M$ and $\lambda \leq \frac{P_m}{P_M - c}$. Given $P_M = \ell_M$, the consumer is indifferent between accepting and rejecting $R = T_M$; and given $\lambda(P_M - \alpha c) < \lambda(P_M - c) \leq P_m$, both expert types optimally choose honest recommendations. Thus $\sigma^H = \sigma^L = 0$ and $\lambda \in (0, 1)$ are indeed mutually best responses. The two types' expected profits as a function of the pooling price P_p are respectively:

$$\Pi^H(P_p) = q(P_M - \alpha c)\lambda + (1-q)P_m, \qquad \Pi^L(P_p) = q(P_M - c)\lambda + (1-q)P_m. \tag{26}$$

Moveover any price list $P_p \neq (\ell_m, \ell_M)$ cannot be supported in a pooling equilibrium. Suppose it is instead. Given the most unfavorable off-equilibrium path belief $\mu(L \mid P) = 1$ if $P \neq P_p$, at least one type of the expert can profitably deviate to $P' \neq (\ell_m, \ell_M)$ because

$$\Pi^H(P_p) \leq \ell_m - \frac{\ell_m}{\ell_M - c}(\alpha - 1)cq = \Pi^H(P'), \qquad \Pi^L(P_p) \leq \ell_m = \Pi^L(P'), \tag{27}$$

where at least one of the inequalities holds strictly so that condition (15) is violated. Thus $P_p = (\ell_m, \ell_M)$ is the unique price list supported in a pooling equilibrium with $\sigma^L = 0$. The expert's profits follow from (26) directly.

We now show that the price-pooling equilibrium, $P_p = (\ell_m, \ell_M)$ with $\sigma^L = 0$, survives the intuitive criterion. For any deviation that is profitable for the high-cost type, such a deviation is also profitable for the low-cost type because the latter gets a larger profit margin by imitating the price choice of the high-cost type. Consider any feasible deviation $P' = (\ell_m - \delta, \ell_M - \epsilon)$, where $\delta \geq 0$, $\epsilon \geq 0$ and $\delta + \epsilon > 0$. The most favorable belief given P' is $\mu(H \mid P') = 1$, and following such belief the consumer accepts $R = T_M$ with probability $\lambda' = \min\{\frac{\ell_m - \delta}{\ell_M - \alpha c - \varepsilon}, 1\}$. For $\lambda' < 1$, the two types' deviation profits are:

$$\Pi^L(P') = \lambda'(\ell_M - \epsilon - c) = (\ell_M - \epsilon - c)\frac{\ell_m - \delta}{\ell_M - \alpha c - \epsilon},$$
$$\Pi^H(P') = q(\ell_M - \epsilon - \alpha c)\lambda' + (1-q)(\ell_m - \delta) = \ell_m - \delta.$$

For any P' that leads to $\Pi^H(P') > \Pi^H(P_p)$, $\delta < \frac{\ell_m}{\ell_M - c}(\alpha-1)cq$ holds. It follows that

$$\Pi^L(P') > \ell_m(1 - \frac{(\alpha-1)cq}{\ell_M - c})(1 + \frac{(\alpha-1)c}{\ell_M - \alpha c}) = \ell_m \frac{\ell_M - c - (\alpha-1)cq}{\ell_M - \alpha c} > \ell_m > \Pi^L(P_p).$$

Thus there exists no price deviation P' such that the high-cost type is strictly better off and the low-cost type is strictly worse off compared with their equilibrium profits.

Similarly, for $\lambda' = 1$, $\Pi^L(P') \geq \ell_M - \epsilon - c$ and $\Pi^H(P') = q(\ell_M - \epsilon - \alpha c) + (1-q)(\ell_m - \delta)$. $\Pi^L(P') < \Pi^L(P_p)$ implies $\ell_M - \epsilon - c < \ell_m$, which in turn implies $\Pi^H(P') < \ell_m - q(\alpha-1)c - (1-q)\delta < \Pi^H(P_p)$. Thus any deviation that decreases the low-cost type's profit must decrease the high-cost type's profit as well. Therefore, we conclude that the equilibrium in Proposition 4 survives the intuitive criterion. ■

Proof of Proposition 5. Consider a price-pooling equilibrium P_p with $\sigma^L = 1$. We have shown that if $\sigma^L = 1$, the high-cost type will choose $\sigma^H \in [0,1)$ and in equilibrium either $\sigma^H \in (0,1)$ or $\sigma^H = 0$ holds. In either case, $\lambda = 0$ implies $P_m = 0$, which is obviously dominated for both expert types. Thus, $\lambda > 0$ holds in equilibrium. Therefore, we have four combinations to consider in the subsequent analysis: (1) $\sigma^H \in (0,1)$ and $\lambda = 1$; (2) $\sigma^H \in (0,1)$ and $\lambda \in (0,1)$; (3) $\sigma^H = 0$ and $\lambda \in (0,1)$; (4) $\sigma^H = 0$ and $\lambda = 1$.

(1) Consider $\sigma^H \in (0,1)$ and $\lambda = 1$. For the high-cost type to be indifferent between $R = T_m$ and $R = T_M$ when $\theta = m$, $\lambda(P_M - \alpha c) = P_m$ which leads to $P_M = P_m + \alpha c$. For the consumer to accept $R = T_M$ with probability one, the following inequality must hold:

$$-\frac{q}{q + (1-q)(x + (1-x)\sigma^H)}\ell_M - \frac{(1-q)(x + (1-x)\sigma^H)}{q + (1-q)(x + (1-x)\sigma^H)}\ell_m \leq -P_M, \tag{28}$$

which simplifies to $P_M \leq \frac{q\ell_M + (1-q)(x + (1-x)\sigma^H)\ell_m}{q + (1-q)(x + (1-x)\sigma^H)}$. Given such prices and the belief that $\mu(H \mid P_p) = 1 - x$ and $\mu(H \mid P) = 0$ for $P \neq P_p$, $\sigma^L = 1$, $\sigma^H \in (0,1)$ and $\lambda = 1$ are mutually best responses. And the expert's expected profits are:

$$\Pi^H(P_p) = P_m, \qquad \Pi^L(P_p) = P_m + \alpha c - c.$$

Using condition (15) for the existence of price-pooling equilibrium, it follows that price list P_p with $\sigma^L = 1$, $\sigma^H \in (0,1)$ and $\lambda = 1$ can be supported in an equilibrium *if and only if*:

$$P_m \in [\ell_m - \frac{\ell_m}{\ell_M - c}(\alpha-1)cq, \frac{q\ell_M + (1-q)(x + (1-x)\sigma^H)\ell_m}{q + (1-q)(x + (1-x)\sigma^H)} - \alpha c], \quad \text{and} \quad P_M = P_m + \alpha c. \tag{29}$$

Thus for $x < \frac{q}{1-q}\frac{\ell_M - \ell_m - \alpha c + \ell_m(\alpha-1)cq/(\ell_M - c)}{\alpha c - \ell_m(\alpha-1)cq/(\ell_M - c)}$, there exist pooling equilibria with $P_p = (P_m, P_m + \alpha c)$,

$\sigma^L = 1$, $\sigma^H \in (0, \bar{\sigma}^H]$, where $P_m \leq \ell_m$ is given by (29) and $\bar{\sigma}^H \in (0,1)$ is derived from:

$$\ell_m - \frac{\ell_m}{\ell_M - c}(\alpha - 1)cq = \frac{q\ell_M + (1-q)(x + (1-x)\bar{\sigma}^H)\ell_m}{q + (1-q)(x + (1-x)\bar{\sigma}^H)} - \alpha c.$$

However, any P_p with $P_m < \ell_m$ cannot survive the intuitive criterion. Suppose there is such an equilibrium. Let $P' = (P_m + \epsilon_h, P_m + \alpha c - \epsilon_l)$ where $\epsilon_h > \frac{q}{1-q}\epsilon_l > 0$, given $\mu(H|P') = 1$, it follows $\lambda = 1$ and $\sigma^H = 0$ and $\sigma^L = 1$, and the two types' deviation profits are:

$$\Pi^H(P') = q(P_m - \epsilon_l) + (1-q)(P_m + \epsilon_h) > \Pi^H(P_p);$$
$$\Pi^L(P') = P_m + (\alpha - 1)c - \epsilon_l < \Pi^L(P_p).$$

Since such deviation is only profitable for the high-cost type, the consumer should hold the belief $\mu(H|P') = 1$ by the intuitive criterion, and the high-cost type would then prefer P' to P_p which is a contradiction.

Consider P_p with $P_m = \ell_m$. Then $\Pi^H(P_p) = \ell_m$, and there exists no deviation that strictly increases the high-cost type's profit above $\Pi^H(P_p)$ but decreases the low-cost type's profit below $\Pi^L(P_p)$ when the expert is considered to be high-cost type. Therefore, the pooling-price list P_p with $P_m = \ell_m$ survives the intuitive criterion. For P_p with $P_m = \ell_m$ to be supported in equilibrium, it is required $x < \frac{q}{1-q}\frac{\ell_M - \ell_m - \alpha c}{\alpha c} = \underline{x}$ and $\sigma^H \leq \frac{q(\ell_M - \ell_m - \alpha c)}{(1-x)(1-q)\alpha c} - \frac{x}{1-x} \in (0,1)$. Therefore, we conclude that when $x < \underline{x}$, there is a continuum of price-pooling equilibria that survive the intuitive criterion:

$$P_p = (P_m, P_M) = (\ell_m, \ell_m + \alpha c);$$
$$\sigma^L = 1, \quad \sigma^H \in (0, \tfrac{q(\ell_M - \ell_m - \alpha c)}{(1-x)(1-q)\alpha c} - \tfrac{x}{1-x}], \quad \lambda = 1. \tag{E-1}$$
$$\Pi^H(P_p) = \ell_m, \quad \Pi^L(P_p) = \ell_m + \alpha c - c.$$

(2) Consider $\sigma^H \in (0,1)$ and $\lambda \in (0,1)$. It follows that condition (28) holds with equality so that the consumer is indifferent between accepting $R = T_m$ and $R = T_M$. Thus

$$P_M = \frac{q\ell_M + (1-q)(x + (1-x)\sigma^H)\ell_m}{q + (1-q)(x + (1-x)\sigma^H)} > P_m + \alpha c. \tag{30}$$

Given such prices and the belief system $\mu(H \mid P_p) = 1 - x$ and $\mu(H \mid P) = 0$ for $P \neq P_p$, $\sigma^L = 1$, $\sigma^H \in (0,1)$ and $\lambda = \frac{P_m}{P_M - \alpha c} \in (0,1)$ are mutually best responses. And the expected profits of the two types are

$$\Pi^H(P_p) = P_m, \qquad \Pi^L(P_p) = (P_M - c)\frac{P_m}{P_M - \alpha c}.$$

For $\Pi^H(P_p)$ and $\Pi^L(P_p)$ to satisfy condition (15), P_m must satisfy

$$P_m \in [\ell_m - \frac{\ell_m}{\ell_M - c}(\alpha - 1)cq, \frac{q\ell_M + (1-q)(x + (1-x)\sigma^H)\ell_m}{q + (1-q)(x + (1-x)\sigma^H)} - \alpha c).$$

However, any P_p with $P_m < \ell_m$ violates the intuitive criterion. Suppose there is indeed such an equilibrium. Then consider $P' = (P_m + \epsilon, \ell_M)$ and $\mu(H|P') = 1$, then $\Pi^H(P') = P_m + \epsilon > \Pi^H(P_p)$ while $\Pi^L(P') = \frac{P_m+\epsilon}{\ell_M - \alpha c}(\ell_M - c) < \frac{P_m}{P_M - \alpha c}(P_M - c) = \Pi^L(P_p)$ for sufficiently small positive ϵ. Thus, intuitive criterion requires $\mu(H \mid P') = 1$ and the high-cost type prefers P' over P_p which is a contradiction.

On the other hand, the price list P_p with $P_m = \ell_m$ (which requires $x < \underline{x}$ and $\sigma^H < \frac{q(\ell_M - \ell_m - \alpha c)}{(1-x)(1-q)\alpha c} - \frac{x}{1-x}$) survives the intuitive criterion since $\Pi^H(P_p) = \ell_m$, and there exists no price deviation strictly increasing the type H seller's profit over $\Pi^H(P_p)$ and decreasing the low-cost type's profit below $\Pi^L(P_p)$. Since $P_m = \ell_m$ implies $P_M \in (\ell_m + \alpha c, \frac{q\ell_M + (1-q)x\ell_m}{q + (1-q)x})$ by (30), we conclude that when $x < \underline{x}$, there is a continuum of price-pooling equilibria that survive the intuitive criterion:

$$\begin{aligned}
&P_m = \ell_m, \quad P_M \in (\ell_m + \alpha c, \tfrac{q\ell_M + (1-q)x\ell_m}{q + (1-q)x}); \\
&\sigma^L = 1, \quad \sigma^H = \tfrac{q(\ell_M - P_M)}{(1-x)(1-q)(P_M - \ell_m)} - \tfrac{x}{1-x}, \quad \lambda = \tfrac{\ell_m}{P_M - \alpha c}. \\
&\Pi^H(P_p) = \ell_m, \quad \Pi^L(P_p) = \tfrac{\ell_m}{P_M - \alpha c}(P_M - c).
\end{aligned} \tag{E-2}$$

(3) Consider $\sigma^H = 0$ and $\lambda \in (0,1)$. It follows that $\lambda(P_M - \alpha c) \le P_m \le \lambda(P_M - c)$. The consumer is indifferent between accepting and rejecting $R = T_M$. Therefore, (28) holds with equality and simplifies to:

$$P_M = \frac{q\ell_M + x(1-q)\ell_m}{q + x(1-q)} \tag{31}$$

after applying $\sigma^H = 0$. By $\lambda \in [\frac{P_m}{P_M - c}, \frac{P_m}{P_M - \alpha c}]$ and the tie-breaking rule that the consumer chooses the largest one when she is indifferent between multiple acceptance rates, we have $\lambda = \frac{P_m}{P_M - \alpha c} \in (0,1)$. Given a price list P_p with $P_m \in (0, P_M - \alpha c)$, and $P_M = \frac{q\ell_M + x(1-q)\ell_m}{q + x(1-q)}$, $\sigma^H = 0$, $\sigma^L = 1$ and $\lambda = \frac{P_m}{P_M - \alpha c} \in (0,1)$ are mutually best responses. If P_p is supported in equilibrium, the two types' expected profits are respectively:

$$\Pi^H(P_p) = P_m, \qquad \Pi^L(P_p) = \frac{P_m}{P_M - \alpha c}(P_M - c).$$

Applying condition (15) a pooling equilibrium with $P_m \in (0, P_M - \alpha c)$, and $P_M = \frac{q\ell_M + x(1-q)\ell_m}{q+x(1-q)}$ exists if and only if

$$P_m \geq \ell_m - \frac{\ell_m}{\ell_M - c}(\alpha - 1)cq, \qquad \frac{P_m}{P_M - \alpha c}(P_M - c) \geq \ell_m.$$

However, any price list P_p with $P_m < \ell_m$ violates the intuitive criterion. Suppose in equilibrium $P_m < \ell_m$. Then consider $P' = (P_m + \epsilon, \ell_M)$ and given $\mu(H|P') = 1$, $\lambda' = \frac{P_m+\epsilon}{\ell_M - \alpha c}$ and for sufficiently small $\epsilon > 0$ the two types' profits satisfy

$$\Pi^H(P') = P_m + \epsilon > \Pi^H(P_p),$$
$$\Pi^L(P') = \lambda'(\ell_M - c) = (P_m + \epsilon)(1 + \frac{(\alpha-1)c}{\ell_M - \alpha c}) < \Pi^L(P_p)$$

and thus, P_p with $P_m < \ell_m$ fails the intuitive criterion. It follows that the only equilibrium surviving the intuitive criterion has $P_m = \ell_m$, which requires $x < \underline{x}$ (so that $P_M - \alpha c > \ell_m$). Thus we conclude that when $x < \underline{x}$, there is a price-pooling equilibrium that survives the intuitive criterion with

$$\begin{gathered} P_m = \ell_m, \quad P_M = \tfrac{q\ell_M + x(1-q)\ell_m}{q+x(1-q)}; \qquad \sigma^L = 1, \quad \sigma^H = 0, \quad \lambda = \tfrac{\ell_m}{P_M - \alpha c}. \\ \Pi^H(P_p) = \ell_m, \qquad \Pi^L(P_p) = \tfrac{\ell_m}{P_M - \alpha c}(P_M - c). \end{gathered} \tag{E-3}$$

(4) Consider $\sigma^H = 0$ and $\lambda = 1$. Condition (28) for the consumer leads to:

$$P_M \leq \frac{q\ell_M + x(1-q)\ell_m}{q + x(1-q)}, \tag{32}$$

and $P_m \in [P_M - \alpha c, P_M - c]$. Given such prices, $\sigma^L = 1$, $\sigma^H = 0$ and $\lambda = 1$ are mutually best responses. Applying condition (15), pooling at P_p with $P_m \in [P_M - \alpha c, P_M - c]$, and $P_M \leq \frac{q\ell_M + x(1-q)\ell_m}{q+x(1-q)}$ is an equilibrium if and only if

$$\Pi^H(P_p) = q(P_M - \alpha c) + (1-q)P_m \geq \ell_m - \frac{\ell_m}{\ell_M - c}(\alpha - 1)cq, \tag{33}$$
$$\Pi^L(P_p) = P_M - c \geq \ell_m. \tag{34}$$

Notice that $P_m = P_M - c$ cannot be supported in equilibrium. Suppose $P_m = P_M - c$ holds, $\Pi^L(P_p) = P_m$. For (34) to be satisfied, we must have $P_m = \ell_m$. However, this in turn leads to $\Pi^H(P_p) = \ell_m - (\alpha - 1)cq < \ell_m - \frac{\ell_m}{\ell_M - c}(\alpha - 1)cq$ not satisfying (33). Thus, $P_m < P_M - c$ holds in equilibrium and this allows us to eliminate any equilibrium with $P_m < \ell_m$ by the intuitive criterion. Suppose there exists an equilibrium P_p with $P_m < \ell_m$. Then consider deviation $P' = (P_m + \epsilon_h, P_M - \epsilon_l)$. For sufficiently small ϵ_l and ϵ_h such that $0 < \epsilon_l < \frac{1-q}{q}\epsilon_h$, we have $\lambda' = 1$ and $\sigma^H = 0$, $\sigma^L = 1$. Then using $\Pi^H(P_p)$ and $\Pi^L(P_p)$ in (33) and (34), we have

$$\Pi^H(P') = q(P_M - \epsilon_l - \alpha c) + (1-q)(P_m + \epsilon_h) > \Pi^H(P_p),$$
$$\Pi^L(P') = P_M - \epsilon_l - c < \Pi^L(P_p),$$

showing that P_p fails the intuitive criterion.

Thus, a price-pooling equilibrium with $P_m = \ell_m$ exists if and only if $P_M \in [\ell_m + \alpha c - \frac{\ell_m}{\ell_M - c}(\alpha - 1)c, \min\{\ell_m + \alpha c, \frac{q\ell_M + x(1-q)\ell_m}{q + x(1-q)}\}]$. Note that

$$\ell_m + \alpha c \lesseqgtr \frac{q\ell_M + x(1-q)\ell_m}{q + x(1-q)} \Leftrightarrow x \lesseqgtr \underline{x} \tag{35}$$
$$\ell_m + \alpha c - \frac{\ell_m}{\ell_M - c}(\alpha - 1)c \leq \frac{q\ell_M + x(1-q)\ell_m}{q + x(1-q)} \Leftrightarrow x \leq \bar{x}. \tag{36}$$

The conditions for the existence of the equilibrium can be equivalently written as

(i) When $x < \underline{x}$, the equilibrium exists if and only if $P_M \in [\ell_m + \alpha c - \frac{\ell_m}{\ell_M - c}(\alpha - 1)c, \ell_m + \alpha c]$;

(ii) When $x \in [\underline{x}, \bar{x}]$, the equilibrium exists if and only if $P_M \in [\ell_m + \alpha c - \frac{\ell_m}{\ell_M - c}(\alpha - 1)c, \frac{q\ell_M + x(1-q)\ell_m}{q + x(1-q)}]$.

In case (i) with $x < \underline{x}$, when $P_M = \ell_m + \alpha c$, the equilibrium survives the intuitive criterion since both expert types get the highest possible profit, $\Pi^H(P_p) = \ell_m$ and $\Pi^L(P_p) = \ell_m + (\alpha - 1)c$. Moreover, we show that if $q > 1 - \frac{\ell_M - \ell_m - c}{\ell_M - c}\frac{\ell_M - \alpha c}{\ell_m}$, no equilibrium with $P_M < \ell_m + \alpha c$ survives the intuitive criterion. Suppose a pooling equilibrium with such a P_M indeed exists. Consider deviation $P' = (\Pi^H(P_p) + \epsilon, \ell_M)$, such that for belief $\mu(H \mid P') = 1$, $\lambda = \frac{\Pi^H(P_p) + \epsilon}{\ell_M - \alpha c}$, $\sigma^L = 1$ and $\sigma^H = 0$ and

$$\Pi^H(P') = \Pi^H(P_p) + \epsilon > \Pi^H(P_p) = q(P_M - \alpha c) + (1-q)\ell_m, \tag{37}$$
$$\Pi^L(P') = \lambda(\ell_M - c) = \frac{q(P_M - \alpha c) + (1-q)\ell_m + \epsilon}{\ell_M - \alpha c}(\ell_M - c) < \Pi^L(P_p). \tag{38}$$

Thus an equilibrium with $P_M < \ell_m + \alpha c$ fails the intuitive criterion. Note that deviation P' increases the high-cost type's profit marginally over $\Pi^H(P_p)$ while ensuring the minimum imitation incentive for the low-cost type. If the low-cost type's profit under P' is not lower than $\Pi^L(P_p)$, then there exists no price deviation that benefits the high-cost type but hurts the low-cost type. When $q > 1 - \frac{\ell_M - \ell_m - c}{\ell_M - c}\frac{\ell_M - \alpha c}{\ell_m}$, for any P_p with $P_M < \ell_m + \alpha c$, there always exists P' such that (38) is satisfied.

When $q \leq 1 - \frac{\ell_M - \ell_m - c}{\ell_M - c}\frac{\ell_M - \alpha c}{\ell_m}$, (38) holds for $P_M > P_*$ where $P_* \in [\ell_m + \alpha c - \frac{\ell_m}{\ell_M - c}(\alpha - 1)c, \ell_m + \alpha c)$ is defined by

$$\frac{q(P_* - \alpha c) + (1-q)\ell_m}{\ell_M - \alpha c}(\ell_M - c) = P_* - c$$

where the RHS is the low-cost type's profit in a price-pooling equilibrium with $P_M = P_*$, and the LHS is the infimum of his deviation profit by choosing $P' = (\Pi^H(P_p) + \epsilon, P_*)$ and being believed to be a high-cost type. It follows that any equilibrium with $P_M \in (P_*, \ell_m + \alpha c)$ cannot survive the intuitive criterion, and equilibria with $P_M \in [\ell_m + \alpha c - \frac{\ell_m}{\ell_M - c}(\alpha - 1)c, P_*]$ survive the intuitive criterion.

Applying the above analysis to case (ii) where $x \in [\bar{x}, \underline{x}]$, we see that when $q > 1 - \frac{\ell_M - \ell_m - c}{\ell_M - c}\frac{\ell_M - \alpha c}{\ell_m}$, no equilibrium in case (ii) survives the intuitive criterion. When $q \leq 1 - \frac{\ell_M - \ell_m - c}{\ell_M - c}\frac{\ell_M - \alpha c}{\ell_m}$, equilibria with $P_M \in [\ell_m + \alpha c - \frac{\ell_m}{\ell_M - c}(\alpha - 1)c, \min\{P_*, \frac{q\ell_M + x(1-q)\ell_m}{q + x(1-q)}\}]$ survive the intuitive criterion.

Summing up the above two cases, we have

(i) When $x < \underline{x}$, there always exists a price-pooling equilibrium that survives the intuitive criterion:

$$\begin{gathered} P_m = \ell_m, \quad P_M = \ell_m + \alpha c; \qquad \sigma^L = 1, \quad \sigma^H = 0, \quad \lambda = 1. \\ \Pi^H = \ell_m, \quad \Pi^L = \ell_m + (\alpha - 1)c. \end{gathered} \tag{E-4a}$$

When $q \leq 1 - \frac{\ell_M - \ell_m - c}{\ell_M - c}\frac{\ell_M - \alpha c}{\ell_m}$, there also exist a continuum of price-pooling equilibria that survive the intuitive criterion:

$$\begin{gathered} P_m = \ell_m, \quad P_M \in [\ell_m + \alpha c - \tfrac{\ell_m}{\ell_M - c}(\alpha - 1)c, P_*]; \\ \sigma^L = 1, \quad \sigma^H = 0, \quad \lambda = 1. \\ \Pi^H = q(P_M - \alpha c) + (1-q)\ell_m, \quad \Pi^L = P_M - c. \end{gathered} \tag{E-4b}$$

(ii) When $x \in [\underline{x}, \bar{x}]$, and $q \leq 1 - \frac{\ell_M - \ell_m - c}{\ell_M - c}\frac{\ell_M - \alpha c}{\ell_m}$, there exist a continuum of price-pooling equilibria that survive the intuitive criterion:

$$\begin{gathered} P_m = \ell_m, \quad P_M \in [\ell_m + \alpha c - \tfrac{\ell_m}{\ell_M - c}(\alpha - 1)c, \min\{P_*, \tfrac{q\ell_M + x(1-q)\ell_m}{q + x(1-q)}\}]; \\ \sigma^L = 1, \quad \sigma^H = 0, \quad \lambda = 1. \\ \Pi^H = q(P_M - \alpha c) + (1-q)\ell_m, \quad \Pi^L = P_M - c. \end{gathered} \tag{E-5}$$

Finally, comparing the equilibrium profits of the two types in equilibria (E-1) through (E-5), we arrive at the payoff-dominant equilibria in Proposition 5. Note that in the comparison between (E-4a) and (E-1), we applied the tie-breaking rule for the high-cost type (the expert chooses the lowest overtreatment rate when he is indifferent between multiple rates), (E-4a) is chosen instead of (E-1), so that $\sigma^H = 0$ remains as the unique outcome in the first part of Proposition 5. ■

Remark 1 *Suppose the two expert types have heterogeneous costs for a minor treatment. Imposing verifiability on top of liability increases social welfare.*

Proof of Remark 1. In the setting with just liability, the *ex ante* social welfare level is

$$\begin{aligned}\check{W}_L =& - x[q(1-\check{\lambda}^L)\ell_M + q\check{\lambda}^L c + (1-q)k] - (1-x)[q(1-\check{\lambda}^H)\ell_M + q\check{\lambda}^H \alpha c + (1-q)\beta k] \\ =& - q(\ell_M - \ell_m)\left[x\frac{\ell_M}{\ell_M - k} + (1-x)\frac{\ell_M}{\ell_M - \beta k}\right] - q\left[\frac{\ell_m - k}{\ell_M - k}xc + \frac{\ell_m - \beta k}{\ell_M - \beta k}(1-x)\alpha c)\right] \\ & - (1-q)(xk + (1-x)\beta k). \end{aligned} \tag{39}$$

In the setting with both liability and verifiability, the social welfare level associated with an expert of type t is

$$w^t_{LV} = - \left[q\check{\lambda}^t c_t + q(1-\check{\lambda}^t)\ell_M + (1-q)\sigma^t\check{\lambda}^t c_t + (1-q)\sigma^t(1-\check{\lambda}^t)\ell_m + (1-q)(1-\sigma^t)k_t\right]$$

Thus the *ex ante* expected social welfare in the inefficient class of equilibria becomes

$$\check{W}_{LV} = - xw^L_{LV} - (1-x)w^H_{LV} = -q(\ell_M - \ell_m) - xk - (1-x)\beta k. \tag{40}$$

Comparing (39) and (40) leads to $\check{W}_{LV} > \check{W}_L$. ■

Proof of Proposition 6. In the setting with just liability, suppose the consumer visits expert A who has posted prices (P^A_m, P^A_M), taking as given (P^B_m, P^B_M). Following similar analysis for Proposition 1, we can show that

$$\sigma^A = \frac{q(\ell_M - P^A_M)}{(1-q)(P^A_M - \ell_m)}, \quad \lambda^A = \frac{P^A_m}{P^A_M} \tag{41}$$

form mutually best responses. The consumer's expected utility from visiting expert A is

$$\begin{aligned}U^A &= -q\left[\lambda^A P_M^A + (1-\lambda^A)\ell_M\right] - (1-q)\left[(1-\sigma^A)P_m^A + \sigma^A\lambda^A P_M^A + (1-\lambda^A)\sigma^A\ell_m\right] \\ &= -P_m^A - (P_M^A - P_m^A)q\frac{\ell_M - \ell_m}{P_M^A - \ell_m}\end{aligned}$$

which is uniquely maximized at $(P_m^A, P_M^A) = (0, \ell_M)$. Since the two experts engage in simultaneous price setting, the equilibrium prices maximize the consumer's expected utility following the familiar arguments of Betrand competition. Thus, the unique equilibrium in the setting with just liability has $(P_m^i, P_M^i) = (0, \ell_M)$ and $\sigma^i = \lambda^i = 0$, for $i = \{A, B\}$.

In the setting with both liability and verifiability, $\sigma^i = 0$ for $i \in \{A, B\}$ must hold in equilibrium. To see this, suppose there is an equilibrium with $\sigma^A > 0$. Then prices posted by expert A must satisfy $P_M^A - c > P_m^A$. If the consumer visits expert A, her acceptance policy will be $\lambda^A = \frac{P_m^A}{P_M^A - c} \in (0, 1)$. For $\sigma^A > 0$, it holds that $\sigma^A = \frac{q(\ell_M - P_M^A)}{(1-q)(P_M^A - \ell_m)}$. The consumer's expected utility from visiting expert A is given by

$$U^A = -\left(q + (1-q)\sigma^A\right)P_M^A - (1-q)(1-\sigma^A)P_m^A < -P_m^A - \left(q + (1-q)\sigma^A\right)c$$

and expert A's expected profit is $\Pi^A = P_m^A \geq 0$. However, expert B can attract the consumer by posting (P_M^B, P_m^B) with $P_M^B - c = P_m^A$ and $P_m^B = P_m^A$, following which $\sigma^B = 0$ and $\lambda^B = 1$. The consumer's utility from visiting expert B will be

$$U^B = -qP_M^B - (1-q)P_m^B = -q(P_m^A + c) - (1-q)P_m^A = -P_m^A - qc.$$

Since $U^B > U^A$, the consumer will not visit expert A, leading to a contradiction.

An equilibrium with $\sigma^i = 0$ implies $P_M^i - c \leq P_m^i$ and $\lambda^i = 1$. The consumer's expected utility from visiting expert i is

$$U^i = -\left(qP_M^i + (1-q)P_m^i\right) \tag{42}$$

which is uniquely maximized at $(P_m^i, P_M^i) = (0, c)$. By the familiar logic of Betrand competition, prices $(P_m^i, P_M^i) = (0, c)$ together with $\sigma^i = 0$ and $\lambda^i = 1$ form the unique equilibrium in the setting of liability and verifiability.

Note that the efficient outcome is achieved in the setting with both liability and verifiability while the equilibrium outcome is inefficient in the setting with just liability because a major problem is unresolved. We conclude that imposing verifiability on top of liability improves social welfare in the competitive expert market. ■

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