The role of diagnostic ability in markets for expert services*

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Abstract

In credence goods markets, experts have better information about the appropriate quality of treatment than their customers. Experts may exploit their informational advantage by defrauding customers. Market institutions have been shown theoretically to be effective in mitigating fraudulent expert behavior. We analyze whether this positive result carries over when experts are heterogeneous in their diagnostic abilities. We find that efficient market outcomes are always possible. However, inefficient equilibria can also exist. When such inefficient equilibria are played, a larger share of high-ability experts can lead to more inefficiencies relative to the efficient equilibria.

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Keywords: Credence good; Diagnosis; Expert; Fraud; Overtreatment; Undertreatment.

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1 Introduction

We theoretically analyze whether and how experts' diagnostic abilities change the market outcome in a credence goods market.[1] A credence good is a good for which customers do not know which type of quality they need. By contrast, experts learn the necessary quality after performing a diagnosis. As experts often perform both the diagnosis and the treatment, experts may exploit their informational advantage in one of three different ways. First, when experts overtreat customers, they provide more expensive treatments than necessary. Second, when experts undertreat their customers, they provide an insufficient treatment. Third, when experts overcharge their customers, they charge for more expensive treatments than provided. In this paper, we focus on the first two forms of fraud and the inefficiencies caused by such a behavior.

Dulleck and Kerschbamer (2006) develop a unifying model of a credence goods market that allows to analyze market efficiency. They highlight that experts serve customers efficiently, i.e., that fraudulent behavior does not occur, when customers are homogeneous with regard to the probability that a major problem occurs, when they are committed to undergoing treatment after receiving a diagnosis, and when either the treatment is verifiable (i.e., overcharging is not possible), or experts are liable (i.e., undertreatment is not possible).

However, these predictions appear to contradict real-life observations. In the healthcare market, for example, the FBI estimates that up to 10% of the 3.3 trillion US$ of yearly health expenditures in the United States are due to fraud (Federal Bureau of Investigation, 2011).[2] Gottschalk et al. (2018) show that 28% of dentists' treatment recommendations involve overtreatment recommendations. In car repair services, Taylor (1995), Schneider (2012), and Rasch and Waibel (2018) report fraud performed by garages. Fraud in computer repair services has been documented by Kerschbamer et al. (2016). Balafoutas et al. (2013) and Balafoutas et al. (2017) document fraud in the market for taxi rides. Moreover, fraudulent behavior has been reported in several lab experiments on credence goods (see, e.g., Dulleck et al., 2011; Mimra et al., 2016a,b).[3]

One explanation for fraud in expert markets under verifiability is given by Kerschbamer et al. (2017). The authors find theoretical and experimental

[1]The seminal article on credence goods markets is by Darby and Karni (1973). For a comprehensive survey of the literature and a unifying model, see Dulleck and Kerschbamer (2006) (see also below).

[2]For an overview of the phenomenon of so-called physician-induced demand (PID), see McGuire (2000).

[3]Kerschbamer and Sutter (2017) provide an overview of the experimental literature on credence goods markets.

evidence that inefficient market outcomes with fraud may arise due to the heterogeneity in experts' social preferences. In particular, experts displaying a strong inequity aversion are reported to overtreat or undertreat customers to reduce differences in payoffs. A second explanation has been put forward by Hilger (2016). Hilger (2016) extends Dulleck and Kerschbamer (2006)'s model by assuming heterogeneity in experts' treatment costs. Treatment costs are no longer observable to customers. Hence, experts cannot credibly signal to provide the appropriate treatment anymore.[4] As a consequence, experts cannot credibly signal that they will always provide the efficient treatment. Then, experts can take advantage of their expert status, resulting in equilibrium mistreatment in a wide range of price-setting and market environments.[5]

We suggest another explanation why (inefficient) overtreatment and/or undertreatment occurs: heterogeneity in experts' diagnostic abilities. Experts can have low or high diagnostic ability, but customers do not observe the type of experts with whom they interact. We are interested in how such differences in diagnostic quality affects expert behavior and market efficiency, and whether better diagnostic abilities yield more efficient outcomes. In contrast to earlier contributions (see the literature overview below), we assume that diagnosis outcomes are exogenous, i.e., more effort or higher investments do not affect diagnostic quality. This has important welfare implications because always recommending the major or minor treatment can now be socially optimal. Our model thus captures situations that require talent, experience, or specific knowledge (e.g., mathematical skills), which cannot be acquired or extended in the short term. Furthermore, capacity or time constraints may limit the experts' opportunities to invest into their diagnostic abilities in the short run.

One area in which our assumptions with regard to differences in diagnostic abilities and the impossibility to change these in the short term appear to be realistic are medical diagnoses. Brush et al. (2017) provide an overview of research which analyzes diagnostic decision-making by expert clinicians. According to the so-called dual process theory, two definable systems of thinking can be distinguished: Whereas "System 1" thinking is intuitive, automatic, quick, and effortless (i.e., non-analytical), "System 2" thinking is analytic, reflective, slow, and effortful. The authors highlight the importance of expertise and experience when they conclude that "[t]he ability to rapidly access experiential knowledge is a hallmark of expertise. Knowledge-oriented interventions such as self-explanation, deliberate reflection, and checklists may improve di-

[4] Liu (2011) and Heinzel (2019a) study a credence goods market with selfish and conscientious experts. The authors show that the existence of conscientious experts in a market may lead to a more fraudulent behavior of the selfish type.

[5] Heinzel (2019b) studies the impact of expert heterogeneity with respect to cost for treating a minor problem on the patients' search for second opinions.

agnostic accuracy, but there is no substitute for experience gained through broad clinical exposure and regular feedback on patient outcomes" (pp. 632–633). More generally, our model captures all interactions in credence goods markets that require immediate care.

Our results can be summarized as follows. As a benchmark, we analyze the situation in which expert types are known. In this case, we find that a low-ability expert – just like a high-ability expert – always efficiently serves the market. In contrast to a high-ability expert type, however, such efficient behavior can require to always perform the major or minor treatment. With unobservable types, multiple pooling equilibria exist. There always exists an efficient equilibrium. Depending on the diagnostic ability and the probability for a high-ability expert type, inefficient equilibria can also exist. An inefficient equilibrium is characterized by the low-ability expert type relying on the diagnosis too often, by both types always providing the major treatment, or by both types always providing the minor treatment. When expert types coordinate on the inefficient equilibria, a higher probability for a high-ability expert type can aggravate relative market inefficiencies. The intuition is as follows: Assume experts coordinate on an equilibrium in which both expert types always provide the major treatment. Then, increasing the probability for a high-ability expert type would improve the market outcome in the efficient equilibria, as more correct diagnoses are performed. However, in contrast to these efficient equilibria, a high-ability expert type sticks to always providing a major treatment in the inefficient equilibria. A similar reasoning applies for a marginal improvement in the low-ability's diagnostic ability. If the expert and the customer coordinate on an equilibrium in which both expert types exclusively provide the major treatment, the improvement in diagnostic ability does not lead to a better market outcomes.

The literature on heterogeneity in credence goods markets is scarce. There is some evidence that the efficiency benchmark result with homogeneous experts and customers and liability or verifiability breaks down as soon as heterogeneity is introduced. The paper closest to ours is Schneider and Bizer (2017a), who offer an extension of the setup in Pesendorfer and Wolinsky (2003). Whereas Pesendorfer and Wolinsky (2003) assume that experts are homogeneous and must decide whether they exert high or low diagnosis effort, Schneider and Bizer (2017a) consider two types of experts. Again, both types must decide whether to exert high or low diagnosis effort, and both types perform an accurate diagnosis when they choose high effort. However, experts differ when they decide to only exert low effort: In this case, the low-ability expert type always misdiagnoses a customer's problem, which is drawn from a continuum of problems, but the high-ability expert type recommends the accurate treatment with some probability. In contrast to the present setup, customers can search for multiple opinions. The authors find that with a sufficient number of high-ability experts, there is the possibility for a second-best equilibrium in which welfare is maximized even without a policy intervention of fixing prices. Moreover, in line with Pesendorfer and Wolinsky (2003), given a small share of high-ability experts, a second-best equilibrium requires fixed prices.

Schneider and Bizer (2017b) experimentally test this model. They find that experimental credence goods markets with expert moral hazard regarding the provision of truthful diagnoses are more efficient than predicted by theory. With regard to better expert qualification (in the sense of a larger share of high-ability experts), the authors find that market efficiency increases with fixed prices but remains unaffected or even declines with price competition.

Dulleck and Kerschbamer (2009) investigate credence goods markets with heterogeneous experts in a retail environment.[6] Customers need a costly diagnosis to find out which service they need. High-ability experts ("specialized dealers") can provide a diagnosis, whereas low-ability experts ("discounters") cannot. High-ability experts can provide both minor and major services. In contrast, low-ability experts can only provide the minor service. In a dynamic set-up in which customers can visit multiple experts, the incentive for experts to provide a diagnosis diminishes if customers' switching costs are sufficiently low.

Bester and Dahm (2017) build on Dulleck and Kerschbamer (2009) and allow for an additional service in the second period in case the service in period one turns out to be insufficient, where the delay in service is costly. The authors show that if the delay costs are sufficiently high – i.e., if a second service does not improve customers' utilities –, the first-best allocation can be implemented.

Frankel and Schwarz (2014) also employ a dynamic set-up. Experts are heterogeneous with respect to their costs. Customers return to an expert who provides the minor treatment and visit another expert with positive probability if they receive a major treatment if costs are observable. If experts' costs are not observable for customers, the first best cannot be implemented.

The remainder of the paper is organized as follows. In the next section, we describe the model setup. In Section 3, we derive the equilibria, distinguishing between the cases of observable types (Subsection 3.1) and unobservable types (Subsection 3.2). In Section 4, we discuss the different equilibria in terms of efficiency and comparative statics. Section 5 concludes and provides some policy implications.

[6] Fong (2005), Dulleck and Kerschbamer (2006), Hyndman and Ozerturk (2011), and Jost et al. (2019) study customer heterogeneity in credence goods markets.

2 Model

Consider the following credence good market with a mass one of customers and a monopolistic expert. Each customer is aware that they have a problem and that they need a major treatment with probability h or a minor treatment with probability $1 - h$. Each customer decides whether to visit an expert. When customers decide to do so, they are committed to undergoing the recommended treatment and paying the price charged for that treatment. Customers can observe the treatment performed and see whether the treatment is sufficient to heal the problem. Hence, customers can observe undertreatment but not overtreatment. If the problem is healed, a customer receives a gross payoff equal to v. If it is not healed, a customer receives a gross payoff of zero. By assumption, a customer who is indifferent between visiting an expert and not visiting an expert decides in favor of a visit.

The expert can be one of two types, which is common knowledge. When the expert has high diagnostic ability, which happens with commonly known probability x, he performs an accurate diagnosis with certainty (at no cost), i.e., he identifies the necessary treatment without making mistakes.[7] When the expert has low ability, which happens with probability $1 - x$, he performs an accurate diagnosis with commonly known probability $q \in [1/2, 1)$.[8] Hence, a low-ability expert can make two types of errors, which occur both with probability $1 - q$: When the expert makes a false positive error, he diagnoses a major problem, although the customer only has a minor problem. Under a false negative error, the expert diagnoses a minor problem, but the customer has a major problem. The expert has costs of $\bar{c}$ and $\underline{c}$ for providing the major and minor treatment, respectively (with $\underline{c} < \bar{c}$). The major treatment heals any of the two problems, whereas the minor treatment only heals the minor problem. We assume that $v > \bar{c}$ holds, which means that it is always (i.e., even ex post) efficient to treat a customer. Furthermore, the expert sets prices $\bar{p}$ and $\underline{p}$ for the major and minor treatment, respectively, and charges the customer for the recommended (verifiable) treatment. An expert's profit amounts to the price-cost margin per customer treated. When customers do not visit the expert, he makes zero profit. We assume that an expert cannot be held liable when providing an insufficient treatment.

The timing of events is as follows:

[7] Our results would not change qualitatively if the high-ability expert type also made mistakes (with a lower probability than the low-ability expert type).

[8] Note that a probability lower than one half does not make sense, as in this case, the expert could provide better services by performing the treatment that was *not* diagnosed.

1. Nature determines whether the expert has high ability (with probability x) or low ability (with probability $1-x$).

2. The expert learns his type and chooses a price vector $\mathbf{P} = \left(\bar{p}, \underline{p}\right)$, which specifies a price for each of the two treatments.

3. Customers observe the prices, form beliefs $\mu(\mathbf{P})$ that an expert setting a price vector $\mathbf{P}$ is a high-ability expert, and decide whether to visit the expert. When customers do not visit the expert, the game ends, and both players receive payoffs of zero.

4. When customers visit the expert, nature determines whether they have a major problem (with probability h) or a minor problem (with probability $1-h$).

5. When the expert has low ability, nature determines the outcome of the diagnosis, which is accurate with probability q. A low-ability expert type has beliefs $\bar{\mu}$ ($\underline{\mu}$) that a customer indeed faces the major (minor) problem when the diagnosis points to a major (minor) problem. A high-ability expert type always performs an accurate diagnosis.

6. The expert recommends and performs a treatment and charges the price for that treatment. Then, payoffs realize.

3 Analysis and results

We now derive the (non-trivial) equilibrium outcomes in the credence goods market specified above. We distinguish between two cases in which expert types are (i) observable and (ii) unobservable. We start by analyzing the benchmark case with observable types.

3.1 Benchmark: Observable types

In order to analyze the optimal pricing and treatment decisions by the two expert types, we look at the relative price-cost margins for the two treatments.

3.1.1 Price-cost margins

Three scenarios are possible: (i) The profit margin is larger for the major treatment; (ii) the profit margin is larger for the minor treatment; and (iii)

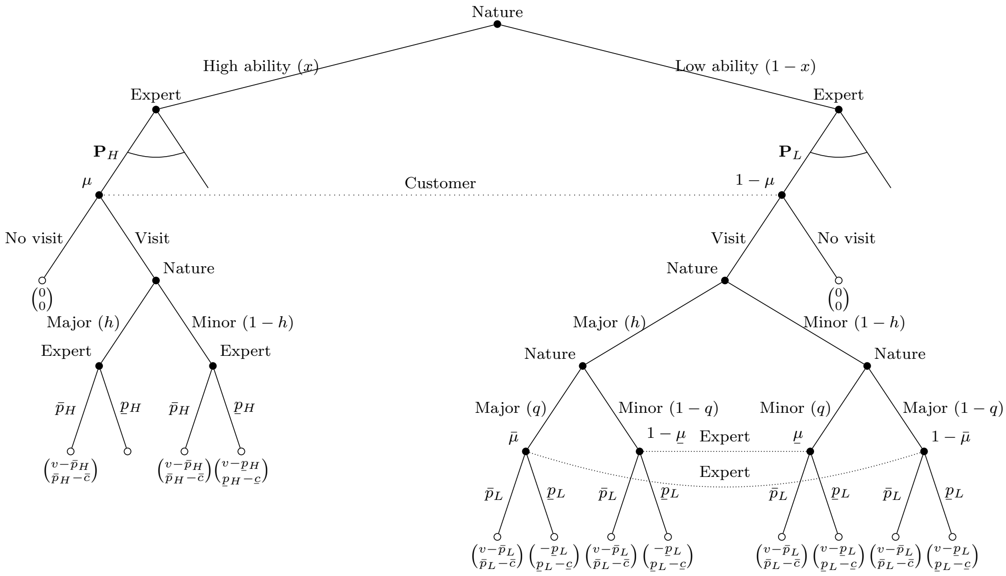

Figure 1: Timing of events in the expert market.

Notes: We refrain from explicitly stating the treatment choice in the game tree because due to verifiability, the expert's price choice implies the respective treatment. Note further that the first (second) entry in the payoff vector represents customer (expert) payoff.

the profit margins for the major and the minor treatment are the same. We focus on those equilibria that yield the highest profits in each (sub-)scenario.

In scenario (i), an expert – independent of his type (and, hence, observability) – finds it optimal to only recommend the major treatment, which implies that even for a high-ability expert type overtreatment occurs sometimes. Denote this case by superscript o, and note that a monopolistic expert always appropriates all surplus from trade, which means that optimal prices are given by

$$\bar{p}^{\circ} = v \tag{1}$$

and

$$\underline{p}^{\circ} \leq v - \Delta c. \tag{2}$$

Here, $\Delta c := \bar{c} - \underline{c}$ denotes the difference in treatment costs. The resulting profit amounts to

$$\pi^{\mathrm{o}} = v - \bar{c}. \tag{3}$$

In scenario (ii), an expert – again independent of his type – finds it optimal to exclusively recommend the minor treatment to his customers. This means that even a high-ability expert type always chooses the minor treatment and this, sometimes undertreats his customers. In this case denoted by superscript u, optimal prices are given by

$$\bar{p}^{\mathrm{u}} \leq (1-h)v + \Delta c \tag{4}$$

and

$$\underline{p}^{\mathrm{u}} = (1-h)v. \tag{5}$$

The profit in this case amounts to

$$\pi^{\mathrm{u}} = (1-h)v - \underline{c}. \tag{6}$$

Given the observability of types, the pricing decision in scenario (iii), denoted by superscript e, depends on the expert's type because different abilities result in different expected gains from trade for customers.[9] Then, for a high-ability expert type (denoted by subscript H), the combination of the customers' binding participation constraint and equal markups leads to prices of

$$\bar{p}^{\mathrm{e}}_{H} = v + (1-h)\Delta c$$

and

$$\underline{p}^{\mathrm{e}}_{H} = v - h\Delta c.$$

The profit for this expert type equals

$$\pi^{\mathrm{e}}_{H} = v - \underline{c} - h\Delta c. \tag{7}$$

Similarly, the prices set by the low-ability expert type, denoted by subscript L, amount to

[9]Scenario (iii) is a special case of the other two scenarios, but for the sake of brevity, we will not repeat the analyses of (i) and (ii) when analyzing (iii), although they also apply.

$$\bar{p}_L^{\text{e}} = (1 - h + hq)\, v + (h - 2hq + q)\, \Delta c$$

and

$$\underline{p}_L^{\text{e}} = (1 - h + hq)\, v - (1 - h + 2hq - q)\, \Delta c.$$

The profit for this type equals

$$\pi_L^{\text{e}} = (1 - h + hq)\, v - \bar{c} + (h - 2hq + q)\, \Delta c. \tag{8}$$

Note that it holds that

$$\frac{\partial \pi_L^{\text{e}}}{\partial q} = hv + (1 - 2h)\Delta c > 0, \tag{9}$$

which is due to the fact that $v > \bar{c}$. Not surprisingly, as customers' expected benefit from visiting an expert increases with the probability of receiving the accurate (sufficient) treatment, profits increase with better abilities.

Before characterizing the two types' optimal pricing behavior, let us briefly comment on efficiency. As the expert can fully extract the surplus, the expert is interested in maximizing customers' expected valuation. As a consequence, whenever an expert opts for a certain pricing scheme given observability of the type, this is also optimal from a social welfare point of view. As mentioned, profits under equal markups increase with better abilities, which means that the same is true for welfare.

Let $\mathbf{P}^{\text{o}} := \left(\bar{p}^{\text{o}}, \underline{p}^{\text{o}}\right)$, $\mathbf{P}^{\text{u}} := \left(\bar{p}^{\text{u}}, \underline{p}^{\text{u}}\right)$, and $\mathbf{P}_i^{\text{e}} := \left(\bar{p}_i^{\text{e}}, \underline{p}_i^{\text{e}}\right)$ (with $i \in \{H, L\}$). We can now analyze the pricing and treatment decisions of the two types. We start with the high-ability expert type.

3.1.2 High-ability expert type

The pricing behavior by the high-ability expert type, if the expert can commit to a strategy, has been studied before and can be characterized as follows:

Lemma 1 (Dulleck and Kerschbamer, 2006)**.** *An observable high-ability expert type efficiently serves all customers and sets a price vector* $\mathbf{P}_H^{\text{e}}$.

Proof. Follows from a straightforward comparison of expression (7) and expressions (3) and (6), respectively, and the assumption that $v > \bar{c}$. □

We can thus point out that the high-ability expert type benefits from offering equal-markup prices. By doing so, the expert can charge higher markups, as the expert credibly commits to treating customers honestly. At the same time, any problem is healed at the lowest cost, i.e., welfare is maximized.

3.1.3 Low-ability expert type

In order to specify the optimal prices set by a low-ability expert, we note that

$$\pi^{\mathrm{o}} \lesseqgtr \pi_L^{\mathrm{e}} \Leftrightarrow h \lesseqgtr \frac{q\Delta c}{(1-q)v-(1-2q)\Delta c} =: h_L^{\mathrm{o}}$$

and

$$\pi^{\mathrm{u}} \lesseqgtr \pi_L^{\mathrm{e}} \Leftrightarrow h \gtreqless \frac{(1-q)\Delta c}{qv+(1-2q)\Delta c} =: h_L^{\mathrm{u}}.$$

Given these comparisons and definitions, we can state the following proposition:

Proposition 1. *Given that a low-ability expert type makes diagnosis errors, an observable low-ability expert type efficiently serves his customers and sets the following prices:*

$$\begin{cases} \mathbf{P}^{\mathrm{u}} & \text{if } h \in [0, h_L^{\mathrm{u}}]\,, \\ \mathbf{P}_L^{\mathrm{e}} & \text{if } h \in (h_L^{\mathrm{u}}, h_L^{\mathrm{o}}], \\ \mathbf{P}^{\mathrm{o}} & \text{else.} \end{cases}$$

Figure 2 illustrates the pricing and treatment decisions by the low-ability expert type. As described, the expert's and the social planner's incentives are fully aligned. Hence, always choosing the major or the minor treatment can also be optimal from a welfare perspective. For example, when the probability of a major problem is not too low, and the probability of an accurate diagnosis is not too high, it is optimal to always recommend and perform the major treatment because the likelihood of failing to heal the customer's problem is greater than that of unnecessarily incurring the higher costs.

We now turn to the case with unobservable expert types.

3.2 Unobservable types

In this part, we first present a general feature of the equilibrium outcomes in our setup. We then derive the equilibria and discuss two refinements.

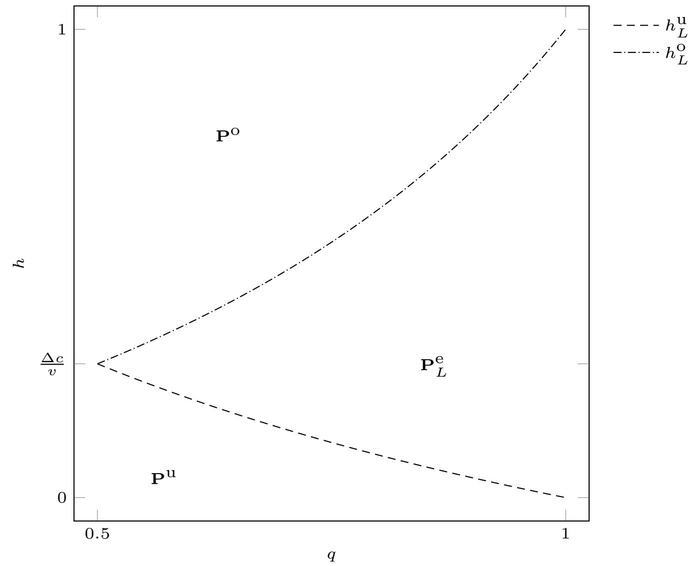

Figure 2: Pricing of an observable low-ability expert type.

3.2.1 Preliminaries

With regard to equilibrium profits, we can state the following:

Lemma 2. *In any equilibrium, both expert types make the same profit.*

Proof. If one expert type made a strictly higher profit in an equilibrium by posting a certain price menu, the other type could easily mimic this offer and make the same strictly higher profit. As ability does not directly affect profits here, both types make the same profit as long as they charge the same prices. □

There are equilibria in which different expert types post the price same vector as well as separating equilibria. In the price-pooling equilibria, different expert types achieve identical profits because their costs do not differ. For any separating equilibrium, there is a price-pooling equilibrium in which the expert provides the same treatment, and the customer pays the same price. The only difference between the two equilibria concerns the price for the treatment that is never chosen. Hence, we have:

Corollary 1. *For any separating equilibrium, there is an outcome equivalent without separation in prices.*

Thus, we focus on non-trivial pure-strategy perfect Bayesian Nash equilibria with price pooling. Among those, we focus on the ones which yield the highest profits.[10]

3.2.2 Definition and existence of equilibria with price pooling

Given the comparison of the two price-cost margins, there are three classes of equilibria: price pooling with (i) only major-treatment recommendations, with (ii) only minor-treatment recommendations, and with (iii) equal markups. The prices and profits for the first two scenarios are the same as in Subsection 3.1 (see expressions (1)–(6)).

In order to simplify the definition of the equilibria, we define the following values of the probability for a high-ability expert type:

$$\bar{x}^{\mathrm{o}} := 1 - \frac{(1-h)\Delta c}{(1-q)(hv + (1-2h)\Delta c)}$$

and

$$\bar{x}^{\mathrm{u}} := \frac{-hqv + (1-q-h+2hq)\Delta c}{(1-q)(hv - (1-2h)\Delta c)}.$$

We start by defining the first class of equilibria:

Definition 1 (Major-treatment equilibria)**.** *Major-treatment equilibria with price pooling are characterized as follows:*

- *Both expert types choose the price vector* $\mathbf{P}^{\circ}$*.*
- *Both expert types always recommend and perform the major treatment.*
- *The low-ability expert type has beliefs* $\bar{\mu} = \underline{\mu} = q$*.*
- *Customers' beliefs equal* $\mu(\mathbf{P}^{\circ}) = x$, $\mu\left(\mathbf{P} = \left(\forall \underline{p} \in \left(\underline{p} | \underline{p} - \underline{c} < \bar{p} - \bar{c}\right), \bar{p} < \bar{p}^{\circ}\right)\right) \in [0,1]$*, and* $\mu(\mathbf{P}) \in [0, \bar{x}^{\circ}]$ $\forall \mathbf{P} > \mathbf{P}^{\circ}$.
- *Customers always visit the expert.*

[10]Additional equilibria exist in which both expert types provide the same treatments but post uniformly lower prices. Customers have off-equilibrium beliefs that any expert posting higher prices is a low-ability expert with sufficiently high probability. Hence, a customer would not visit the expert that posts higher prices.

Next we define the second class of equilibria:

Definition 2 (Minor-treatment equilibria)**.** *Minor-treatment equilibria with price pooling are characterized as follows:*

- *Both expert types choose the price vector* $\mathbf{P}^{\mathrm{u}}$.
- *Both expert types always recommend and perform the minor treatment.*
- *The low-ability expert type has beliefs* $\bar{\mu} = \underline{\mu} = q$.
- *Customers' beliefs equal* $\mu(\mathbf{P}^{\mathrm{u}}) = x$, $\mu(\mathbf{P}) \in [0, 1]\ \forall \mathbf{P} < \mathbf{P}^{\mathrm{u}}$, *and* $\mu(\mathbf{P}) \in [0, \bar{x}^{\mathrm{u}}]\ \forall \mathbf{P} > \mathbf{P}^{\mathrm{u}}$.
- *Customers always visit the expert.*

Let us briefly comment on the structure of these equilibria. In the major-recommendation equilibria with price pooling, both types of experts choose their price vectors, such that they always optimally recommend the major treatment, independent of the customer's problem. Analogously, in the minor-recommendation equilibria with price pooling, both types choose their price vectors, such that it is always optimal to recommend the minor treatment. A low-ability expert type believes to have received the correct diagnosis with a probability that is equal to the accuracy of his diagnosis. Given that both expert types set identical prices, i.e., no information concerning expert types is conveyed, customers believe to face a certain expert type with the ex ante probability that this type is chosen by nature whenever the major-treatment (or minor-treatment, respectively) price vector is observed. With regard to customers' off-equilibrium beliefs, we distinguish two cases: First, when customers observe prices which are lower than those actually charged along the equilibrium path, there is no restriction with respect to the beliefs. This is due to the fact that both expert types do not have any incentive to set lower prices in the first place because this would only result in lower profits. Second, customers would be willing to pay a higher price to the high-ability type when they receive an appropriate treatment with a higher probability in return. This means that they must have a sufficiently weak belief that an expert setting higher prices than those to be charged along the equilibrium path indeed has high ability.

We now turn to equal-markup equilibria. In those, each type of expert may choose to either condition the treatment on the diagnosis or to always perform one of the two treatments. Thus, special cases of the major-treatment and minor-treatment equilibria can be equal-markup equilibria. When both types of experts follow the diagnosis, prices and profits for equal markups are given by

$$\bar{p}^{\mathrm{e}} = (1 - h + hq - hqx + hx)\, v + (h - 2hq + 2hqx - 2hx + q - qx + x)\, \Delta c$$

and

$$\underline{p}^{\mathrm{e}} = (1 - h + hq - hqx + hx)\, v - (1 - h + 2hq - 2hqx + 2hx - q + qx - x)\, \Delta c.$$

Then, let $\mathbf{P}^{\mathrm{e}} := \left(\bar{p}^{\mathrm{e}}, \underline{p}^{\mathrm{e}}\right)$. The profit for each type equals

$$\pi^{\mathrm{e}} = (1 - h + hq - hqx + hx)\, v \\ - \underline{c} - (1 - h + 2hq - 2hqx + 2hx - q + qx - x)\, \Delta c. \quad (10)$$

Again, both types make identical profits because ability does not play any role under equal-markup prices: Even when a low-ability expert type recommends the wrong treatment, the expert receives the same mark-up as the high-ability expert type.

A comparison of profits reveals that

$$\pi^{\mathrm{o}} \lesseqgtr \pi^{\mathrm{e}} \Leftrightarrow h \lesseqgtr \frac{(q - qx + x)\Delta c}{(1 - q + qx - x)v - (1 - 2q + 2qx - 2x)\Delta c} =: h^{\mathrm{o}}$$

and

$$\pi^{\mathrm{u}} \lesseqgtr \pi^{\mathrm{e}} \Leftrightarrow h \gtreqless \frac{(1 - q + qx - x)\Delta c}{(q - qx + x)v + (1 - 2q + 2qx - 2x)\Delta c} =: h^{\mathrm{u}}$$

It holds that

$$\frac{\partial h^{\mathrm{o}}}{\partial q}, \frac{\partial h^{\mathrm{o}}}{\partial x} > 0, \quad (11)$$

and

$$\frac{\partial h^{\mathrm{u}}}{\partial q}, \frac{\partial h^{\mathrm{u}}}{\partial x} < 0. \tag{12}$$

Thus, both probabilities have a very similar effect on the two thresholds. This is due to the fact that the scenarios with only major-treatment/minor-treatment recommendations are affected by neither of the two probabilities because the two expert types do not differ in their recommendations. Under equal mark-up pricing, social welfare is affected by diagnostic quality. However, because the expected gain from interaction is always zero for the customer, it does not make any difference for the customer whether the customer faces a high-ability expert with probability x (and consequently receives the accurate treatment with certainty), or whether the customer faces a low-ability expert type and receives the accurate treatment with probability q from an ex ante point of view.

More generally, let $\mathbf{P}^{\mathrm{e}}_{jk} := \left(\bar{p}^{\mathrm{e}}_{jk}, \underline{p}^{\mathrm{e}}_{jk}\right)$, where $j \in \{d, o, u\}$ specifies whether the high-ability expert type always follows his diagnosis or recommends the major or the minor treatment, where $k \in \{d, o, u\}$ characterizes the respective recommendation decision for the low-ability expert type, and where

$$\begin{aligned}\bar{p}^{\mathrm{e}}_{jk} = \underline{p}^{\mathrm{e}}_{jk} + \Delta c = x\left[\mathbb{1}_{j=o} v + \mathbb{1}_{j=u}((1-h)v + \Delta c) + \mathbb{1}_{j=a}(v + (1-h)\Delta c)\right]\\ + (1-x)\left[\mathbb{1}_{k=o} v + \mathbb{1}_{k=u}((1-h)v + \Delta c)\right.\\ \left.+\mathbb{1}_{k=a}(v(1-h(1-q)) + ((1-h)q + h(1-q))\Delta c)\right].\end{aligned} \tag{13}$$

The profits are $\pi^{\mathrm{e}}_{jk} = \bar{p}^{\mathrm{e}}_{jk} - \bar{c}$.

Given the above prices, we can define equal-markup equilibria:

Definition 3 (Equal-markup equilibria)**.** *Equal-markup equilibria with price pooling are characterized as follows:*

- *Both expert types choose the price vector* $\mathbf{P}^{\mathrm{e}}_{jk}$*.*
- $j \in \{d, o, u\}$ *specifies whether the high-ability expert type always follows his diagnosis or recommends and performs the major or the minor treatment, and* $k \in \{o, u, a\}$ *does so for the low-ability expert type.*
- *The low-ability expert type has beliefs* $\bar{\mu} = \underline{\mu} = q$*.*
- *Customers' beliefs equal* $\mu\left(\mathbf{P}^{\mathrm{e}}_{jk}\right) = x$*,* $\mu(\mathbf{P}) \in [0,1]$ $\forall \mathbf{P} < \mathbf{P}^{\mathrm{e}}_{jk}$*, and* $\mu(\mathbf{P}) \in [0, x]$ $\forall \mathbf{P} > \mathbf{P}^{\mathrm{e}}_{jk}$*.*

- *Customers always visit the expert.*

Given identical markups, any treatment recommendation is equally profitable for an expert – independent of his type. As in the previously defined equilibria, a low-ability expert type believes to have received the correct diagnosis with a probability that equals the accuracy of his diagnosis. Again no information concerning expert types is revealed through the price setting, which means that customers believe they face a certain expert type with this type's (ex ante) probability to be selected by nature whenever the equal-markup price vector is posted by the expert. With regard to customers' off-equilibrium beliefs, prices which are higher than those to be charged along the equilibrium path must be accompanied by a sufficiently weak belief that the expert has high ability.[11] Again, there is no restriction with respect to the beliefs when customers observe prices which are lower than those charged along the equilibrium path.

Using these definitions, we can thus state equilibrium existence as follows:

Proposition 2. *The existence of equilibria with price pooling is characterized as follows:*

(i) for $h \in [0, h^{u}]$*, there exist minor-treatment equilibria;*

(ii) for $h \in [h^{\circ}, 1]$*, there exist major-treatment equilibria;*

(iii) for $h \in [0, 1]$*, there exist equal-markup equilibria.*

There exist several different types of equal-markup equilibria, some of which appear to be implausible. The usual equilibrium selection criteria do not have bite here because the expert's type does not affect his profits directly but only indirectly via equilibrium prices, which depend on customers' beliefs. In the following subsections, we further analyze equal-markup equilibria by imposing two assumptions on equilibrium selection that are relevant in different contexts.

3.2.3 Refinements: Recommendation behavior

Having a closer look at the different recommendation options expert types have when they are indifferent due to equal-markup pricing, we first analyze the case in which experts follow their diagnosis. Then, we analyze the case

[11] We constrain off-equilibrium beliefs in that case by assuming that customers believe that indifferent experts will not hurt them on purpose. More precisely, they believe that indifferent experts either follow their diagnosis or perform the ex-ante optimal treatment. This means that the "worst" off-equilibrium beliefs are either that an expert will recommend the ex ante optimal treatment, or that a low-ability expert will follow his diagnosis.

in which experts maximize their customers' expected utility, which will also maximize equilibrium profits and overall efficiency.

Indifferent expert type follows his diagnosis

A scenario in which both expert types follow their diagnosis when they are indifferent may be relevant if experts are overconfident or completely unaware of their type, or if they might want or need to justify their decision (e.g., presentation of diagnosis outcomes in court).

We describe the set of equilibria in this case in the following proposition:

Proposition 3. *The existence of equilibria with price pooling when indifferent experts follow their diagnosis is characterized as follows:*

(i) for $h \in [0, h_L^u]$, there exist minor-treatment equilibria;

(ii) for $h \in [h^u, h^o]$, there exist equal-markup equilibria in which each expert type follows his diagnosis;and

(iii) for $h \in [h_L^o, 1]$, there exist major-treatment equilibria.

Because $h^u < h_L^u$ and $h^o > h_L^o$, there are multiple equilibria for some values of h but not for others.

Figure 3 illustrates the existence of the different equilibria. In all figures, the size of the gray areas (i. e. combinations of q and h) is determined by customers' off-equilibrium beliefs when observing higher (equal-markup) prices than those to be charged in the respective equilibria. The figures show the largest possible size of gray areas when higher-than-equilibrium equal-markup prices lead customers to believe that they face a low-ability expert type with certainty.

Indifferent expert type maximizes customers' expected utility

If both expert types maximize their customers' expected utility when they are indifferent, after setting the prices, experts behave as if their type were observable, i.e., the high-ability expert type will always follow his diagnosis, whereas the low-ability expert type will only do so if his diagnosis is correct with a sufficiently high probability. Otherwise, the low-ability expert type will always perform the major or the minor treatment, depending on which will lead to a higher expected utility for customers. The set of equilibria in this case is described in the following proposition:

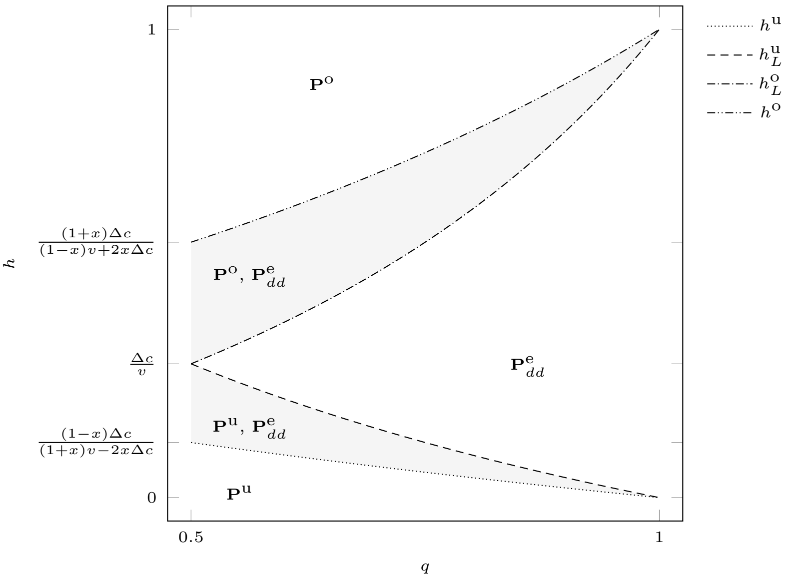

Figure 3: Equilibrium pricing when an indifferent expert type follows his diagnosis.

Note: The size of gray area (i. e. combinations of q and h) is determined by customers' off-equilibrium beliefs when observing higher prices than those to be charged in the respective equilibria. The figure shows the largest possible area when higher-than-equilibrium prices lead customers to believe that they face a low-ability expert type with certainty.

Proposition 4. *The existence of equilibria with price pooling when indifferent experts maximize customers' expected utility is characterized as follows:*

(i) for $h \in [0, h^{\mathrm{u}}_L]$, there exist minor-treatment equilibria;

(ii) for $h \in [h^{\mathrm{o}}_L, 1]$, there exist major-treatment equilibria;

(iii) for $h \in [0, 1]$, there exist equal-markup equilibria. In those, the high-ability expert type always follows his diagnosis. The low-ability expert type follows his diagnosis if $h \in (h^u_L, h^o_L]$, always performs the minor treatment if $h \in [0, h^u_L]$, and always performs the major treatment if $h \in (h^o_L, 1]$.

Figure 4 illustrates the existence of the different equilibria.

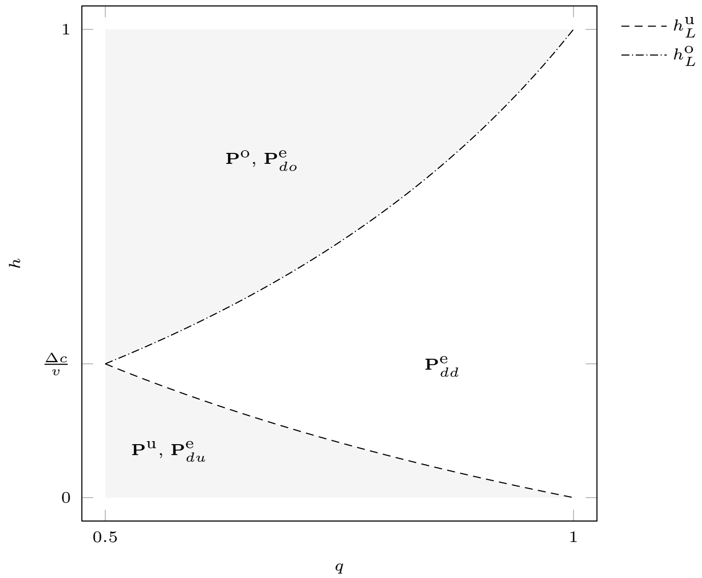

Figure 4: Equilibrium pricing when an indifferent expert type maximizes his customers' expected utility.

Note: The size of gray area (i. e. combinations of q and h) is determined by customers' off-equilibrium beliefs when observing higher prices than those to be charged in the respective equilibria. The figure shows the largest possible area when higher-than-equilibrium prices lead customers to believe that they face a low-ability expert type with certainty.

4 Discussion

In this section, we discuss the welfare properties of the equilibria considered and analyze how better diagnostic outcomes impact the relative efficiency of these equilibria.

4.1 Welfare

We compare social welfare in the equilibria derived in the previous section, where social welfare is defined as the sum of (expected) expert and customer surplus. We consider an equilibrium to be efficient, if – given the diagnostic ability and the ex ante probability of customers having a major problem – there is no strategy that leads to a higher social welfare.

A first observation is that the minor-treatment and the major-treatment equilibria are never efficient because the high-ability type could always provide the correct diagnosis, which would result in cost savings. In contrast, the equal-markup equilibria in which the low-ability expert type maximizes his customers' utility are the efficient equilibria. For $h \in (h_L^{u}, h_L^{o}]$, these efficient equilibria coincide with the equal-markup equilibria in which both expert types follow their diagnosis. For all other parameter values, the equal-markup equilibria in which both expert types follow their diagnosis are inefficient. We can hence state the following result:

Proposition 5. *Consider the equal-markup equilibria in which the high-ability expert type always follows his diagnosis, and the low-ability expert type follows his diagnosis if $h \in (h_L^{u}, h_L^{o}]$, performs the minor treatment if $h \in [0, h_L^{u}]$, and performs the major treatment if $h \in (h_L^{o}, 1]$. These equilibria are efficient. The maximum prices are weakly higher than in any other equal-markup equilibrium with price pooling, and profits at those maximum prices are weakly higher than the profits in any other equilibrium.*

From a policy perspective, it is an important question whether better diagnostic abilities improve the market outcome – in particular when such an endeavor involves substantial costs. Such an improvement can come in two forms: First, the low-ability expert type may become better at supplying an accurate diagnosis (i.e., q increases). Second, the probability that an expert is a high type increases (i.e., x increases). We next discuss each improvement separately. In order to compare equilibrium outcomes, we define the relative efficiency as the share of surplus relative to the surplus under the efficient equilibrium.

4.2 Increase in diagnostic precision

The effect of an increase in the diagnostic precision crucially depends on the ex ante probability of customers having a major problem as well as the equilibrium played. We first outline the impact of an increase in diagnostic precision on social welfare under the efficient equilibria. Then, we compare how relative social welfare in the other equilibria is affected by an increase in diagnostic precision.

For the efficient equilibria and a high ex ante probability of customers having a major problem ($h \in (h_L^{o}, 1]$), the low-ability expert always provides the major treatment. Hence, a marginal increase in the diagnostic precision does not change the surplus. This also holds for a low likelihood that customers suffer from a major problem ($h \in [0, h_L^{u}]$), where the low-ability expert always undertreats independent of his diagnostic signal. In contrast, whenever customers have the major problem with some intermediate probability ($h \in (h_L^{u}, h_L^{o}]$), both expert types follow their diagnostic signal. Then, a more precise diagnosis leads to a higher surplus because the low-ability expert provides the appropriate treatment for customers more often.

Next, we investigate the impact of a higher precision of diagnostic ability in the other equilibria on social welfare relative to the above benchmark. We differentiate three cases based on the ex ante probability that a customer suffers from a major problem h: high ($h > (1+x)\Delta c/((1-x)v + 2x\Delta c)$), medium ($h \in (\Delta c/v, (1+x)\Delta c/((1-x)v + 2x\Delta c))$), and low probability ($h < (1+x)\Delta c/((1-x)v + 2x\Delta c)$).

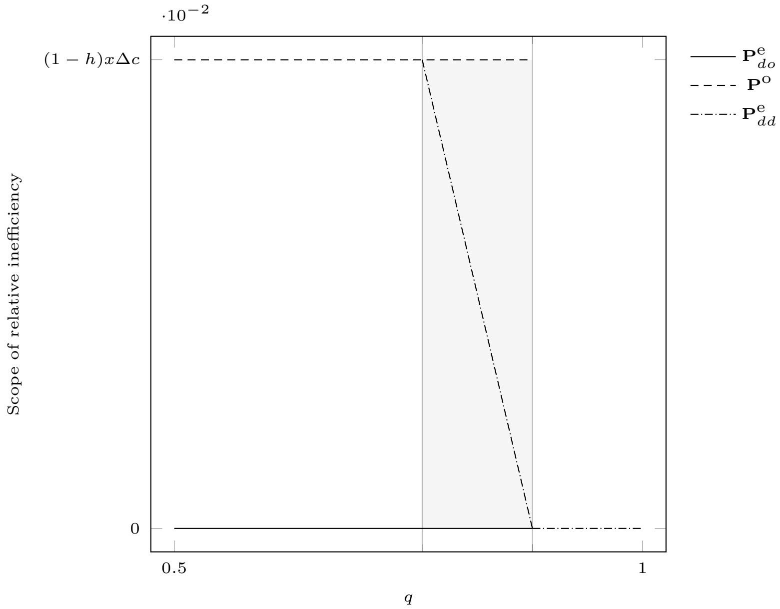

Figure 5: Market (in)efficiency when a major problem occurs with sufficiently high probability ($h > (1+x)\Delta c/((1-x)v + 2x\Delta c)$), and when off-equilibrium beliefs equal zero.

Note: The size of gray area (i. e. combinations of q and h) is determined by customers' off-equilibrium beliefs when observing higher prices than those to be charged in the respective equilibria. The figure shows the largest possible area when higher-than-equilibrium prices lead customers to believe that they face a low-ability expert type with certainty.

For the case of a high probability for the major problem, (inefficient) major-treatment equilibria exist besides the efficient equilibria for low values of q. *Figure 5* illustrates this case. For low values of q, it is efficient that a low-ability expert always provides the major treatment. Hence, an increase in diagnostic precision neither changes the behavior of experts in a major-treatment equilibrium nor in an efficient equilibrium. The relative efficiency of the major-treatment equilibrium does not change. For medium values of q, equal-markup equilibria exist in which both expert types follow their diagnosis. The relative efficiency of these equilibria increases with an increase in diagnostic precision, as the low-ability type's diagnosis becomes more accurate. If customers and the expert coordinate on the major-treatment equilibrium, the increase in diagnostic precision again does not change relative efficiency. For high values of q, only the two equal-markup equilibria exist and coincide. Hence, an increase in diagnostic precision does not change relative efficiency.

In the case with a medium probability for the major problem, the major-treatment equilibria and the equal mark-up equilibria in which experts follow their diagnosis when they are indifferent exist also for low values of q. *Figure 6* displays this case. Starting from a low value of q, an increase in the diagnostic precision leads to a lower relative inefficiency in the equal-markup equilibria in which experts follow their diagnosis. This does not hold for the major-treatment equilibria. There, the relative inefficiency persists. When q is sufficiently high, both equal-markup equilibria coincide.

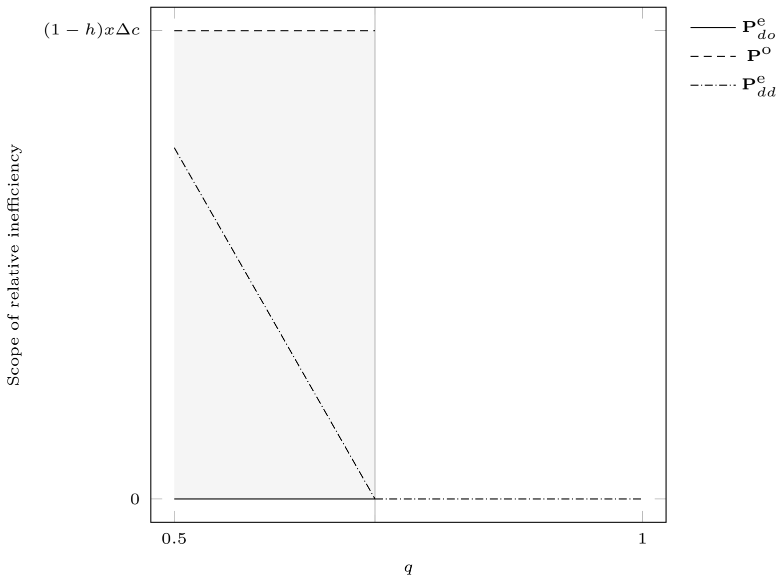

Figure 6: Market (in)efficiency when a major problem occurs with medium probability ($h \in (\Delta c/v, (1+x)\Delta c/((1-x)v+2x\Delta c))$), and when off-equilibrium beliefs equal zero.

Note: The size of gray area (i. e. combinations of q and h) is determined by customers' off-equilibrium beliefs when observing higher prices than those to be charged in the respective equilibria. The figure shows the largest possible area when higher-than-equilibrium prices lead customers to believe that they face a low-ability expert type with certainty.

The case of a low probability for the major problem is analogous to the case of a high probability. We can thus summarize our findings in the following proposition:

Proposition 6. *When both types do not choose an equal-markup price vector for $h \in (h^{u}, h^{u}_{L})$ or $h \in (h^{o}_{L}, h^{o})$, better diagnostic abilities of the low-ability expert type do not decrease relative inefficiencies.*

4.3 Increase in probability of high-ability expert

The second dimension that might be important for a policy-maker is the share of high-ability experts in the market. This section analyzes how such a higher share affects relative efficiency in the market.

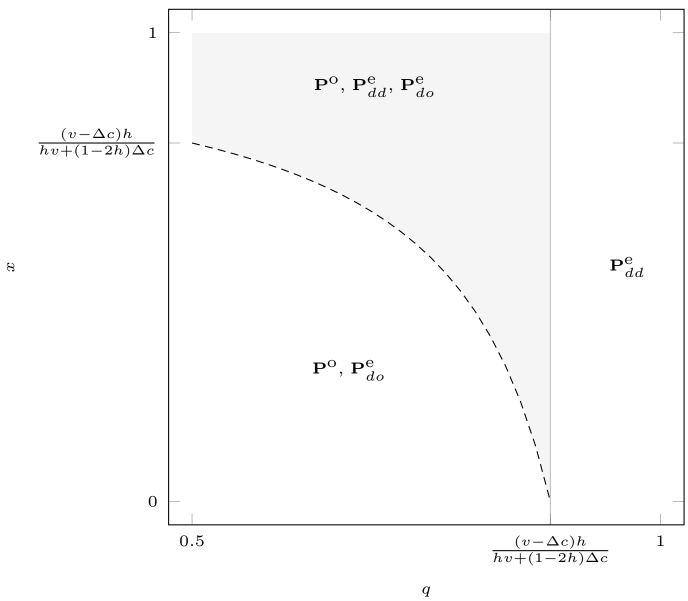

Figure 7: Equilibrium pricing for combinations of q and x (for $h > \Delta c/v$).

Note: The size of gray area (i. e. combinations of q and h) is determined by customers' off-equilibrium beliefs when observing higher prices than those to be charged in the respective equilibria. The figure shows the largest possible area when higher-than-equilibrium prices lead customers to believe that they face a low-ability expert type with certainty.

Figure 7 illustrates the existence of the different equilibria depending on the diagnostic precision and the probability for a high-ability expert type. A first observation is that for relatively precise diagnoses ($q > (v - \Delta c)h/(hv + (1 - 2h)\Delta c)$), only equal-markup equilibria exist. The two equal-markup equilibria coincide. For a lower diagnostic precision ($q \leq (v - \Delta c)h)/(hv + (1 - 2h)\Delta c)$, multiple equilibria that actually lead to different behaviors exist: For lower values of q and high values of x, the major-treatment equilibria and the two types of equal-markup equilibria exist. For lower values of q and x, only the major-treatment equilibria and the efficient equilibria exist.

With regard to the impact of an increase in the probability for a high-ability expert, there is no change in relative efficiency for high values of q ($q > (v - \Delta c)h)/(hv + (1 - 2h)\Delta c)$), where only equal-markup equilibria exist. For lower values of q ($q \leq (v - \Delta c)h/(hv + (1 - 2h)\Delta c)$) and low values of x, an increase in the probability for a high-ability expert type leads to an increase in the surplus under the efficient equilibrium. In the major-treatment equilibria, high-ability experts stick to providing a major treatment, although they could provide the appropriate treatment. Hence, the relative efficiency of major-treatment equilibria increases. For higher values of x, the equilibria in which experts follow their diagnosis also exist.

An increase in x leads to a lower relative inefficiency, as the probability for an incorrect diagnosis by low-ability experts decreases. *Figure 8* illustrates the case for lower values of q.

Note that neither increasing x nor q actually decreases absolute efficiency if there is no direct cost of doing so. However, if increasing those is not free, a policy maker should not make use of this option if players coordinate on the major- or the minor-treatment equilibria. However, as *Figure 7* illustrates, if the policy maker increases q not only marginally but by sufficiently much, those equilibria do not exist anymore. Increasing x to a value smaller than 1 does not have such an effect.

Note: The gray area demonstrates the maximum size of customers' off-equilibrium beliefs when observing higher prices than those to be charged in the respective equilibria.

5 Conclusion

We present a credence goods model with expert types that differ in their diagnostic ability. Whereas a high-ability expert type always performs a correct diagnosis with regard to the customer's problem, a low-ability expert type does not always deliver an accurate diagnosis. Thus, a low-ability expert type sometimes makes mistakes when diagnosing customers. While earlier analyses have assumed that it is possible for experts to incur investment costs to perform an accurate diagnosis, we consider a situation in which a low-ability expert type cannot improve his diagnostic skills. Our setup thus mirrors short-

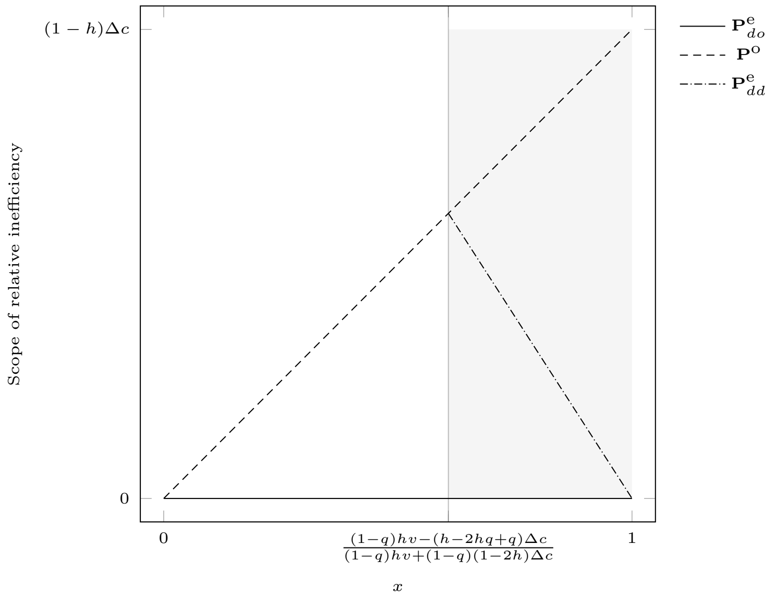

Figure 8: Market (in)efficiency when major problem occurs with sufficiently high probability ($h > \Delta c/v$), when diagnostic quality of the low-ability expert type is sufficiently low ($q < (v - \Delta c)h/(hv + (1 - 2h)\Delta c)$), and when off-equilibrium beliefs equal zero.

term interactions or settings with capacity constraints rather than long-term investments.

In our benchmark case with observable expert types, both expert types post equal-markup prices to signal that they have no incentive to overtreat or undertreat. The high-ability expert posts higher prices than the low-ability type because the customers' valuation for receiving a correct diagnosis (and treatment) is higher than for a possibly incorrect one. Furthermore, profits are higher for the high-ability type than for the low-ability type.

Under unobservable expert types, we find that efficient market outcomes always exist. Nevertheless, expert types may also coordinate on inefficient equilibria. In both – efficient and inefficient – equilibria, the two expert types post equal prices. This is the case because the low-ability experts type could always mimic the high-ability expert type when the latter deviates from equal prices. Hence, markups and profits are identical for both expert types. Increasing transparency, i.e., making expert types observable, would weakly increase social welfare in our set-up.

Relative to the social welfare under efficient equilibria, a marginal increase in the low-ability type's diagnostic ability does not necessarily improve social welfare. Welfare depends on the probability that customers need a major treatment and on the equilibrium experts coordinate on. We find that relative social welfare does not improve if the probability for a major problem is sufficiently high or sufficiently low. Only for an intermediate likelihood, an increase in relative social welfare results if the expert types post equal-markup prices and follow their own diagnosis.

We observe that an increase in the share of the high-ability type can even decrease relative social welfare. If expert types coordinate on an equilibrium in which both expert types always provide the major treatment, increasing the probability for a high-ability expert does not change the behavior of expert types, although the high-ability expert type would be able to provide a correct diagnosis.

A sufficiently large increase in the low-ability type's diagnostic ability can guarantee an efficient equilibrium, increasing the share of high-ability experts would only do so if there was no low-ability type left at all. This implies that increasing minimum standards for experts can be a more successful policy than increasing the share of excellent experts.

We want to highlight that a regulation which only allows to follow the diagnostic results can be detrimental to relative social welfare. Such a regulation supports the efficient equilibrium only if diagnostic precision is sufficiently high. Moreover, it is never optimal to require both expert types to always provide a certain treatment. However, if the policy maker can differentiate expert types, requiring the low-type to always provide a certain treatment is optimal if the low-ability type's ability is sufficiently low. Overall, our results show that a careful design of expert markets is necessary to attain the social optimum.

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