The role of diagnostic ability in markets for expert services

Fang Liu, Alexander Rasch, Marco A. Schwarz, Christian Waibel

European Economic Review 180 (2025) 105126

Contents lists available at ScienceDirect

European Economic Review

journal homepage: www.elsevier.com/locate/eer

The role of diagnostic ability in markets for expert services ☆

Fang Liu [a,b], Alexander Rasch [b], Marco A. Schwarz [b,c,d,*], Christian Waibel

[a] *School of Economics, University of International Business and Economics, China*
[b] *Düsseldorf Institute for Competition Economics (DICE), Faculty of Business Administration and Economics, Germany*
[c] *CESifo, Germany*
[d] *Interdisciplinary Center for Economic Science (ICES), United States of America*

ARTICLE INFO

JEL classification:
D82
L15

Keywords:
Credence good
Diagnosis
Expert
Fraud

ABSTRACT

In credence goods markets, experts have better information about the appropriate quality of treatment than their customers. They may then 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 to a situation in which experts are heterogeneous in their diagnostic abilities. We find that efficient market outcomes are always possible. Inefficient equilibria, however, can also exist. If, in equilibrium, experts provide diagnosis-independent treatments, an increase in the experts' ability or in the probability of high-ability experts might not improve market efficiency.

1. Introduction

In markets for expert services – such as medical treatments, repairs, and financial and legal advice – diagnostic abilities differ across experts and are far from perfect. For instance, Chan et al. (2022) show that skill plays an important role in the pneumonia diagnoses of United States radiologists; Xue et al. (2019) show in their quasi-experimental study that a lack of sufficient diagnostic knowledge is an important driver of the large amount of inappropriate antibiotic prescription in rural China; and the ECDC Technical Report (2019) identifies "uncertain diagnosis" as a common reason for antibiotic prescribing in cases in which prescribers (mostly medical doctors in EU/EEA countries) would have preferred not to prescribe (26% stated this as a reason occurring at least once during the previous week).[1] Nevertheless, the theoretical literature following Dulleck and Kerschbamer (2006) generally assumes that experts can perfectly diagnose their customers' problems, and sometimes makes predictions that do not seem to be in line with real-world observations. For example, Dulleck and Kerschbamer (2006) highlight that fraudulent behavior does not occur, and experts serve customers efficiently when customers are ex ante homogeneous, when they are committed to undergoing treatment after receiving a diagnosis, and when either the treatment is verifiable, or the experts are liable; yet, inadequate treatments are an important issue in real-life credence goods markets.[2]

☆ This article is part of a Special issue entitled: 'Nora Szech' published in European Economic Review.

* Corresponding author at: Düsseldorf Institute for Competition Economics (DICE), Faculty of Business Administration and Economics, Germany.
E-mail addresses: fang.liu@uibe.edu.cn (F. Liu), rasch@dice.hhu.de (A. Rasch), marco.schwarz@hhu.de (M.A. Schwarz), christian.waibel@gmail.com (C. Waibel).

[1] Further examples include Lambert and Wertheimer (1988) (diagnoses of psychopathology), Brammer (2002) (psychological diagnoses), Coderre et al. (2009) (diagnostic performance for clinical problems), Kondori et al. (2011) (diagnoses by dentists), and Mullainathan and Obermeyer (2021) (diagnoses of heart attacks).

[2] In the US healthcare market, for example, the FBI estimates that up to 10% of the 3.3 trillion US$ of yearly health expenditures are due to fraud (Federal Bureau of Investigation, 2011). For an overview of the phenomenon of so-called physician-induced demand (PID), see McGuire (2000). Gottschalk et al. (2020) show that 28% of dentists' treatment recommendations involve overtreatment recommendations. Fraud in repair services has been documented for cars (Taylor, 1995; Schneider, 2012; Rasch and Waibel, 2018), cellphones (Hall et al., 2025), and computers (Kerschbamer et al., 2016, 2023; Bindra et al., 2021). Balafoutas

https://doi.org/10.1016/j.euroecorev.2025.105126
Received 10 February 2024; Received in revised form 31 July 2025; Accepted 15 August 2025
Available online 18 September 2025
0014-2921/

We theoretically analyze whether and how experts' diagnostic abilities change the market outcome in a credence goods market. To this end, we set up a model based on the standard credence goods model by Dulleck and Kerschbamer (2006).[3] 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. Because experts often perform both the diagnosis and the treatment, they 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 insufficient treatments. 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. In our setup, (inefficient) overtreatment and/or undertreatment can occur due to the 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 are interacting. We are interested in how such differences in diagnostic quality affect expert behavior and market efficiency and whether better diagnostic abilities yield more efficient outcomes. In contrast to earlier contributions (see the literature overview in the next section) and motivated by the above-mentioned circumstances in many credence goods markets, our basic model assumes that diagnosis outcomes are exogenous, that is, more effort or higher investments do not affect diagnostic quality. This has important welfare implications because always recommending the major or minor treatment can be socially optimal in this case.

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 who performs a correct diagnosis only with some probability – just like a high-ability expert who always correctly identifies a customer's major or minor problem – efficiently serves the market. In contrast to a high-ability expert type, however, such efficient behavior can require always performing the major or minor treatment.

With unobservable types, we find that the classic benchmark result of full efficiency in the standard setup crucially depends on the assumption of perfect diagnostic ability. Our analysis shows the existence of multiple equilibria when customers do not know the type of expert they are interacting with. Our main contributions are the following.

First, we compare the equilibria with the benchmark case of observable types to highlight the impact of imperfect information on expert types and customers. When types are unknown and the low-ability type pools with the high-ability type at equal-markup prices in equilibrium, the high-ability type cross-subsidizes the low-ability type; that is, the high-ability type makes lower and the low-ability type makes higher profits than if types were observable.

Second, we find that there can be over-utilization and under-utilization of diagnostic information in equilibrium. As customers end up paying higher prices to the low-ability type than they would if the expert was known to have low diagnostic ability, profits under equal-markup prices are higher for the low-ability type than only major and minor treatments over a wider parameter range than in the first-best, efficient scenario. Thus, in an inefficient equal-markup equilibrium in which the low-ability type follows his diagnosis (see also the next paragraph), this finding suggests that asymmetric information about the expert type can lead to excessive use of diagnostic information by low-ability experts. Furthermore, there are also inefficient equilibria in which both expert types always perform the major or minor treatment. Thus, asymmetric information can lead to insufficient use of diagnostic information by the high-ability type.

Third, we show that different equilibria arise under different tie-breaking rules for equal markup prices. Under equal-markup pricing, each type of expert is indifferent between recommending the major treatment and the minor treatment, which means that any recommendation is a best response. We consider the following two tie-breaking rules because standard equilibrium refinements do not have any bite: (i) an indifferent expert follows his diagnosis (for example, because he may have to present diagnoses outcomes in court or to an insurance company), and (ii) an indifferent expert maximizes customers' expected utility (for example, because he has taken the Hippocratic Oath). If an indifferent expert follows his diagnosis, efficient equilibria do not always exist, where the inefficiency stems from the above-mentioned over-utilization or under-utilization of diagnostic information. Alternatively, if an indifferent expert recommends the treatment maximizing the customer's utility, an efficient equilibrium always exists (but there might also be inefficient ones).

Given these results, we can conclude that increasing the observability of types – for example, via certification – weakly increases efficiency in our setting. Furthermore, increasing the probability of a high-ability expert type or marginally improving the low-ability's diagnostic ability can be a pure waste. When the expert types and the customers coordinate on an equilibrium in which both types exclusively provide the major treatment, the increase in the probability of a high-ability expert and the improvement in diagnostic ability do not lead to a better market outcome.[4] We also show that our results are robust to various forms of diagnosis effort and to competition. Moreover, we find that small fines for insufficient treatment are effective policy tools when the success or the failure of a treatment is verifiable. A large fine may induce a separating equilibrium, which may be efficient or inefficient.

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, for instance, Dulleck et al., 2011; Mimra et al., 2016a,b). Kerschbamer and Sutter (2017) provide an overview of the experimental literature on credence goods markets.

[3] The seminal article on credence goods markets is Darby and Karni (1973).

[4] A somewhat related result is found by Jiang et al. (2014) who investigate more vs. less ethical markets, where ethical experts take into account a customer's well-being. The authors find that efficiency and the customer's ex ante expected surplus might be lower in a more ethical market than in a less ethical market. A sufficiently strong increase in the low-ability expert's diagnostic ability (for example, through better education or requiring the use of certain tools supported by artificial intelligence [AI]), however, guarantees an efficient outcome. Dai and Singh (2024), who analyze the case in which the physician uses AI not for diagnostic purposes but for determining a treatment plan, show some limits of the use of AI in healthcare, though.

Our model captures two types of scenarios that represent a wide range of important real-life credence goods markets. First, our setup applies to those markets in which customers require immediate care, and experts must rely on talent, experience, or specific knowledge (for example, mathematical and statistical skills), which cannot be acquired or extended in the short or medium term.[5] Such a limitation to invest in skills may also be due to capacity or time constraints. Another reason for a lack of investment may be that experts are not even aware of their limited skill set for a specific task. On a related note, we stress that incorrect diagnoses occur despite the high entry barriers in such markets in which experts are required to have a specific qualification. This may be due to the fact that certain skills are not included in the curriculum at the certifying stage.[6]

Second, as we show in an extension, our results extend to many situations in which experts exert unobservable effort to improve their diagnostic ability, or in which such effort is observable, but experts are homogeneous with regard to the effort costs involved.

Importantly, we assume that prices are not completely fixed,[7] and that they are at least partially borne by customers, as is the case for most repair services and many dental and some medical treatments in numerous countries. Whereas it is true that the costs for many of the above-mentioned services are covered by insurance, customers often still have to pay rather large amounts for some of these services out of their own pocket.[8] For instance, Adrion et al. (2016) analyze medical claims for inpatient hospitalizations across the United States. The authors find that out-of-pocket spending is substantial, even among insured individuals.[9] For healthcare in China, Li et al. (2017) stress the low reimbursement caps in outpatient care, leading to a coverage of only three to five typical outpatient visits. In addition, not all services are covered by health insurance. On a more general note, according to the OECD (2019), patients in OECD countries, on average, pay one in every five health dollars out of their own pocket, where out-of-pocket payments vary across services and goods. On average, almost two-thirds of dental care spending is paid directly. Moreover, in the United States, the American Mental Health Alliance gives reasons for why it may be better not to use insurance for psychotherapy and opt for out-of-pocket payments instead.[10, 11]

The remainder of the paper is organized as follows. In the next section, we provide an overview of the related literature. We describe the model setup in Section 3. In Section 4, we derive the equilibria, distinguishing between the cases of observable types (Section 4.1) and unobservable types (Section 4.2). In Section 5, we discuss the different equilibria in terms of efficiency and comparative statics and analyze extensions of our model: diagnosis effort, competition, and fines and warranties. Section 6 concludes and provides some policy implications.

2. Related literature

Our paper is related to the literature investigating expert heterogeneity in credence goods markets. Typically, the literature offers evidence that the efficiency benchmark result with homogeneous experts and customers and liability or verifiability breaks down when heterogeneity is introduced.[12] A large part of the literature on expert heterogeneity so far has focused on environments in which experts need to exert unobservable effort to provide a correct diagnosis (hidden action), whereas our approach considers an environment in which the accuracy of the diagnosis is an exogenous, unobservable trait of an expert (hidden type). At first sight, both situations may be qualitatively very similar because customers cannot tell the diagnostic quality in either of the two scenarios, but the strategic implications are quite different. As a consequence and in contrast to our setup, efficient equilibria do not always exist in the scenarios with hidden actions.

The article closest to ours is Dai and Singh (2020) who analyze a model in which the expert can have a high or a low diagnostic ability and can additionally perform a perfectly informative test. In contrast to our model, the expert does not set prices and is not motivated by profits but by a combination of altruism and reputation among his peers. The authors find that in the unique separating equilibrium, the high-ability type does not use the test but the low-ability type does. Due to reputational concerns, the high-ability type might not use the test even when it would be efficient to do so. Although our benchmark result on observable expert types shares some similarities with theirs, our main results are very different from what the authors find. Most importantly, we look at markets in which an additional test like they consider is not readily available. As a consequence, experts cannot use such tests as a

[5] Brush et al. (2017) provide an overview of research that analyzes diagnostic decision-making by expert clinicians. 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 [...] may improve diagnostic accuracy, but there is no substitute for experience gained through broad clinical exposure" (pp. 632–633).

[6] For example, in Germany, there has been criticism over how physicians are not sufficiently trained in mathematics and statistics during their university studies, which may have been problematic for the success of the vaccination campaign to fight the spread of COVID-19 (see https://www.spiegel.de/panorama/bildung/corona-impfung-warum-fehlende- mathekenntnisse-unter-aerzten-den-impferfolg-gefaehrden-a-8ce4fb92-69b9-421 2-9064-cff9b8bbd4b0, accessed on July 5, 2023).

[7] For example, the website clearhealthcosts.com reports that for magnetic resonance imaging (MRI), different facilities (hospital, radiology center, doctor's office) charge a great range of diverging prices. See https://clearhealthcosts.com/blog/2012/11/how-much-does-an-mri-cost-part-2/ (accessed on July 5, 2023).

[8] For experimental studies that analyze the implications of insurance coverage in the context of credence goods markets, see Kerschbamer et al. (2016) and Balafoutas et al. (2023).

[9] Moreover, Pham et al. (2007) use data from a survey among American physicians, and find that physicians do not routinely consider patients' out-of-pocket costs when making decisions with regard to more expensive medical services.

[10] See http://www.americanmentalhealth.com/whyself-pay.trust?cart=1313110291 11492613 (accessed on May 12, 2021).

[11] Note also that co-payments or partial insurance in percentage terms could be readily incorporated into the model, resulting in different equilibrium prices, but without changing the results qualitatively. Because this is not the focus of this paper, we abstract away from such payments.

[12] Emons (1997, 2001) does not rely on heterogeneity, but shows that if a monopolist expert's capacities are not fully utilized, the expert fills these unused capacities through overtreatment. Gottschalk et al. (2020) provide experimental evidence.

signaling device. The equilibria in which experts uniformly use the test in their article do not leave any diagnostic uncertainty and, therefore, do not result in the inefficiencies due to wrong treatments. In fact, customers that downward adjust their beliefs about the expert's type after a deviation from equilibrium can induce experts to use the test in their model, whereas such customers can support diagnosis-independent equilibria in our model.

Schneider and Bizer (2017a) offer an extension of the setup in Pesendorfer and Wolinsky (2003).[13] Whereas Pesendorfer and Wolinsky (2003) assume that experts are homogeneous and must decide whether to exert high or low diagnosis effort, Schneider and Bizer (2017a) consider two types of experts.[14] 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 (in contrast to our setup, where there is always a chance that the low-ability type misdiagnoses the customer's problem). Experts differ, however, when they decide to only exert low effort: In this case, the high-ability expert type recommends the accurate treatment, which is drawn from a continuum of problems, with some probability. Crucially and in contrast to our model, however, the low-ability expert type always misdiagnoses a customer's problem, which leads to different equilibria and welfare effects. 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 of 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.[15] 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.[16] Customers need a costly diagnosis to find out which service they need. High-ability experts ("specialized dealers") can perform a correct diagnosis at costly effort and provide both minor and major services, whereas low-ability experts ("discounters") cannot provide a diagnosis and only provide the service requested by customers.[17] In contrast to the present setup, customers can perfectly tell an expert's ability type and the diagnostic quality of the high-ability expert is endogenous. Furthermore, customers can visit multiple experts at a search cost, and they must pay for the diagnosis performed by a high-ability expert. In their dynamic setup, Dulleck and Kerschbamer (2009) show that the incentive for experts to provide a diagnosis diminishes if customers' switching costs are sufficiently low.[18]

Furthermore, Ayouni and Lanzi (2023) investigate a setting in which there is a chance that a monopolistic expert's diagnosis is always uninformative. They demonstrate that customer feedback may increase overtreatment.

Finally, Crettez et al. (2020) show that awareness campaigns may reduce overtreatment in a setting in which experts have different diagnostic abilities. Crucially, experts in their setting do not set prices, and respond to the moral rather than direct monetary incentives of the different treatments. Moreover, low-ability experts do not get any information from the diagnosis in their setting.

Another set of papers look at very different dimensions of expert heterogeneity that are unrelated to differences in diagnostic abilities and thus complement the mechanisms and policy implications in our paper. Frankel and Schwarz (2014) employ a dynamic setup to study experts who are heterogeneous with regard to their costs. If costs are observable, customers return to an expert who provides the minor treatment and visit another expert with positive probability if they receive a major treatment. If experts' costs are not observable for customers, the first best cannot be implemented. Relatedly, Hilger (2016) extends the model by Dulleck and Kerschbamer (2006) 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.[19] Then, experts can take advantage of their expert status, resulting in equilibrium mistreatment in a wide range of price-setting and market environments.[20]

Moreover, Kerschbamer et al. (2017) find theoretical and experimental evidence that inefficient market outcomes with fraud can 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.

[13] Chen et al. (2022) analyze a model in which experts sometimes have heterogeneous diagnosis costs. Inderst and Ottaviani (2012a,b,c) and Inderst (2015) consider homogeneously imperfect diagnostic abilities in markets for financial advice. Balafoutas et al. (2023) study the interaction of homogeneously imperfect diagnostic abilities and insurance coverage. Fong et al. (2022) analyze a model in which doctors with homogeneously imperfect diagnostic abilities can refer patients to labs for (further) testing. Schniter et al. (2021) experimentally investigate the interaction of a rating system and both (homogeneous) diagnosis and service uncertainty. Liu and Ma (2024) study a generalized credence good model in which loss is a continuous random variable. In an extension with endogenous information acquisition, they show that an expert prefers an imperfect diagnostic ability to avoid an information asymmetry reminiscent of the lemon's problem.

[14] As such, they consider a situation of hidden actions and hidden types.

[15] In a similar framework with ex ante homogeneous experts, Momsen (2021) experimentally investigates how transparency influences outcomes in credence good markets.

[16] Fong (2005), Dulleck and Kerschbamer (2006), Hyndman and Ozerturk (2011), and Jost et al. (2021) study customer heterogeneity in credence goods markets. Szech (2011) analyzes expert heterogeneity in a health-care market with one type of problem.

[17] Alger and Salanié (2006) and Obradovits and Plaickner (2024) also look at settings with (observable) high-ability experts and discounters, but they only consider the case in which the high type's diagnostic ability is exogenously perfect, and the discounter's ability is non-existent.

[18] By contrast, Bester and Dahm (2018) 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 – that is, if a second service does not improve customers' utilities – the first-best allocation can be implemented.

[19] Liu (2011), Fong et al. (2014) (in an extension), 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 can lead to a more fraudulent behavior of the selfish type.

[20] Heinzel (2019b) studies the impact of expert heterogeneity with respect to the cost for treating a minor problem in the customers' search for second opinions. Ely and Välimäki (2003) and Ely et al. (2008) investigate the effects of reputation building in a setting in which experts' different strategies can be interpreted as reflecting cost heterogeneity.

3. Model

Building on Dulleck and Kerschbamer (2006), we consider the following credence good market with a mass one of customers and a monopolistic expert. Customers are aware that they have a problem, and that they need a major treatment with probability h or a minor treatment with probability $1 - h$.[21] Each customer decides whether to visit the expert. When customers decide to do so, they are committed to undergoing the recommended treatment and paying the price charged for that treatment.[22] Customers can verify the treatment performed and can see whether the treatment is sufficient to solve the problem. Hence, customers can observe undertreatment but not overtreatment. If the problem is solved, a customer receives a gross payoff equal to v. If it is not solved, a customer receives a gross payoff of zero. Like most of the literature, we assume that customers are rational and indifferent customers decide in favor of a visit.

The expert can be one of two types, which is common knowledge.[23] When the expert has high diagnostic ability, which happens with commonly known probability x, he performs an accurate diagnosis with certainty (at no cost), that is, he identifies the necessary treatment without making mistakes.[24] When the expert has low ability, which happens with probability $1-x$, he performs an accurate diagnosis with commonly known probability $q \in [1/2, 1)$. Hence, a low-ability expert can make two types of errors, which both occur 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 (with $\underline{c} < \bar{c}$). The major treatment solves any of the two problems, whereas the minor treatment only solves the minor problem. We assume that $v > \bar{c}$ holds, which means that it is always (that is, even ex post) efficient to treat a customer. Furthermore, the expert sets prices $\bar{p}$ and $\underline{p}$ for the major and minor treatment 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, the expert makes zero profit. We assume that the expert is profit-maximizing and cannot be held liable when providing an insufficient treatment.[25]

Formally, each expert type's strategy consists of a non-negative price vector $\mathbf{P} = (\bar{p}, \underline{p})$ and, if the customer visits, a treatment decision (major or minor) that may depend on the expert's signal, his type, and the price vector. A customer decides whether to visit, conditional on the price vector posted (and the expert's type if types are observable — otherwise we require the customer to form Bayesian beliefs whenever possible).

The timing of events, which is illustrated in Fig. 1, is as follows:

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 $\mathbf{P} = (\bar{p}, \underline{p})$, 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 are realized.

4. Analysis and results

Now we 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 employ subgame-perfect equilibria and perfect Bayesian equilibria when analyzing games with complete and incomplete information. By "non-trivial", we mean equilibria with interaction, that is, we exclude equilibria in which the customer believes that an indifferent expert would recommend the opposite of what he should recommend from a customer's point of view, and, therefore, no customer visits an expert. We start by analyzing the benchmark case with observable types.

---

[21] Like most of the literature (see footnote 16 for a few exceptions), we assume that this probability is homogeneous across customers. If it is not (and h is a customer's private information), the expert would face a trade-off between serving all types of customers and charging some customer type the full willingness to pay in most types of equilibria.

[22] A possible justification for this assumption is that search costs may simply be too high, and that these costs are not outweighed by the potential savings from searching for a second opinion and avoiding an unnecessary major treatment. In general, what happens if customers are not committed to undergoing the recommended treatment is already an interesting question in itself (see, for example, Fong et al., 2014). For homogeneous experts, Baumann and Rasch (2024) analyze how diagnostic uncertainty interacts with customers' possibility to search for a second opinion.

[23] One can extend our model to n types. Where applicable, the expert with the lowest ability determines thresholds. Our results do not change qualitatively, but the notation would become cumbersome.

[24] 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). Moreover, our results are largely robust to a (potentially heterogeneous) small positive diagnosis cost (when the performance of a diagnosis is verifiable). It would simply reduce profits as long as both types make non-negative profits. Otherwise, the type with the higher diagnosis cost will not serve any customers.

[25] We discuss liability in Section 5.5.

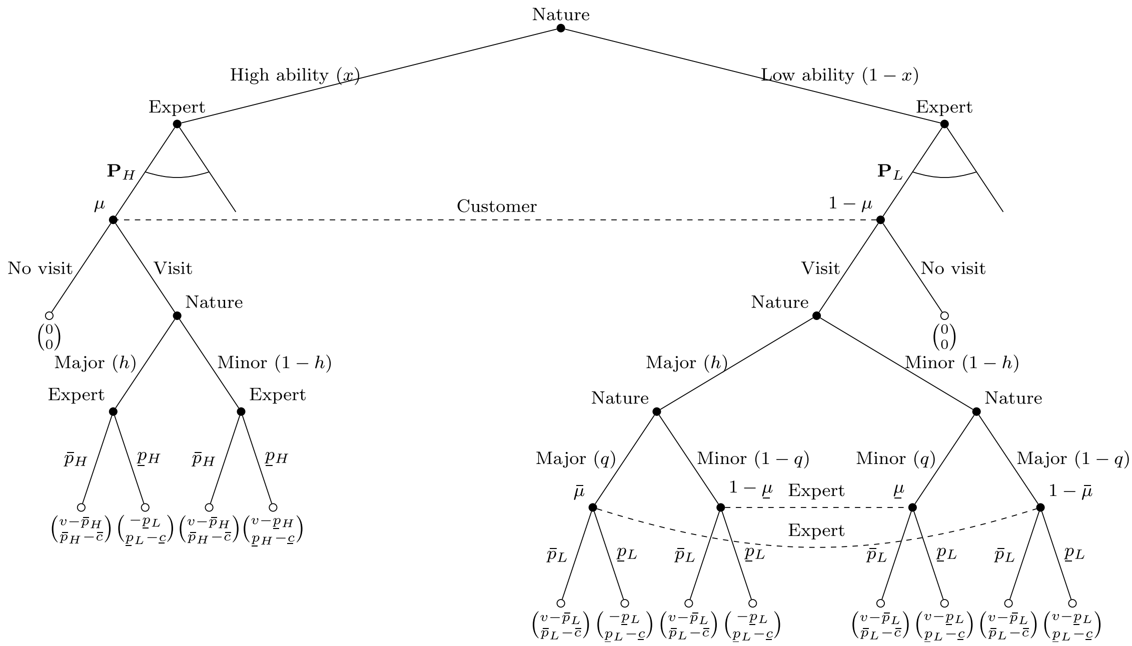

Fig. 1. Timing of events in the expert market.
Notes: We refrain from explicitly stating the treatment choice in the game tree because due to verifiability, the expert's price choice implies the respective treatment. Note further that the first (second) entry in the payoff vector represents customer (expert) payoff.

4.1. Benchmark: Observable types

As a benchmark, we first consider the case in which the customer can observe the expert's type. 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.

4.1.1. 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) 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.

Only major treatments. In scenario (i), the expert – independent of his type (and, hence, observability) – finds it optimal to only recommend the major treatment. 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

$$\bar{p}^{\mathrm{o}} = v \tag{1}$$

and

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

The price for the minor treatment is chosen, such that the profit margin for the minor treatment is weakly smaller than the profit margin for the major treatment. Here, $\Delta c := \bar{c} - \underline{c}$ denotes the difference in treatment costs. The resulting profit amounts to

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

Only minor treatments. In scenario (ii), the expert – again independent of his type – finds it optimal to exclusively recommend the minor treatment to 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

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

Equal markups. 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.[26] Then, for a high-ability expert type (denoted by subscript H), the combination of the customers' binding participation constraint ($v - h\bar{p}^{\mathrm{e}}_{H} - (1-h)\underline{p}^{\mathrm{e}}_{H} = 0$) and equal markups ($\bar{p}^{\mathrm{e}}_{H} - \bar{c} = \underline{p}^{\mathrm{e}}_{H} - \underline{c}$) leads to prices of

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

and

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

Note that the price for the major treatment is larger than customers' valuation (see also Dulleck and Kerschbamer, 2006). This can be explained as follows: The high-ability expert always performs the correct treatment under equal-markup prices and, hence, provides a gross benefit equal to the customers' valuation. The expert, however, cannot charge this valuation for the minor treatment because – due to the lower cost associated with the minor treatment – this would give the expert an incentive to always perform the minor treatment. As a consequence, the price for the minor treatment must be lower than the valuation. Because this means that there is money left on the table, the expert can charge a major-treatment price that is larger than the valuation, and customers (weakly) gain in expectation from visiting the expert.

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) following his diagnosis amount to

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

and

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

The profit for this type equals

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

Note that it holds that

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

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

Efficiency. Before characterizing the two types' optimal pricing behavior, let us briefly comment on the first-best (that is, efficient) outcome. Efficiency is determined by two factors: (i) whether customers' problems are solved, and (ii) at what cost these problems are solved. This means that if the problem can be correctly diagnosed (as is true for the high-ability expert type), providing the appropriate treatment – that is, provision of the major treatment to solve the major problem and provision of the minor treatment to solve the minor problem – is efficient: Customers' gross payoff of v is always realized at the lowest possible cost. Hence, customer surplus gross of prices is maximized. Note that for the expert to have an incentive to provide the appropriate treatment in this situation, equal-markup prices must be optimal.

If the problem cannot be diagnosed with certainty (as is true for the low-ability expert type), the additional costs of (sometimes) providing the more expensive major treatment must be weighed against the increase in the probability that the problem is solved, realizing the customer valuation v. Suppose first that a major problem was diagnosed. Again, it is then optimal to either follow the diagnosis or provide the minor treatment.[27] A comparison of the associated net benefits reveals that

$$v - \bar{c} \lesseqgtr \left(1 - \frac{qh}{qh + (1-q)(1-h)}\right) v - \underline{c} \Leftrightarrow h \lesseqgtr \frac{(1-q)\Delta c}{qv + (1-2q)\Delta c} =: h^{\mathrm{u}}_{L}. \tag{10}$$

Suppose now that the diagnosis indicated that the customer has a minor problem. From an efficiency point of view, it is then optimal to either follow the diagnosis[28] or provide the major treatment. A comparison of the associated net benefits for society gives

[26] 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.

[27] Note that the diagnosis is incorrect with probability

$$1 - \frac{qh}{qh + (1-q)(1-h)}.$$

[28] Note that the diagnosis is correct with probability

$$\frac{q(1-h)}{q(1-h) + (1-q)h}.$$

$$\frac{q(1-h)}{q(1-h)+(1-q)h}v-\underline{c} \lesseqgtr v-\bar{c} \Leftrightarrow h \gtreqless \frac{q\Delta c}{(1-q)v-(1-2q)\Delta c} =: h_L^{\mathrm{o}}. \tag{11}$$

Note that, as expected, it holds that $h_L^{\mathrm{u}} \leq h_L^{\mathrm{o}}$ (see also Fig. 2). From the comparisons, it follows that always choosing the major or the minor treatment can be efficient. More precisely, performing only the major treatment is socially optimal for sufficiently high values of the likelihood of the major problem, that is, $h > h_L^{\mathrm{o}}$. In this case, the expected cost of failing to solve the customer's problem is greater than that of unnecessarily providing the major treatment. Similarly, always opting for the minor treatment is efficient for a low enough likelihood of the major problem, that is, $h \leq h_L^{\mathrm{u}}$. Again, customer surplus gross of prices is maximized.

For further reference, we can summarize the efficient treatment as follows:

Proposition 1 (*Efficient Treatment*). *If a problem can be diagnosed correctly with certainty, efficiency requires that customers get the appropriate treatment. If a problem cannot be diagnosed with certainty, the efficient treatment depends on the likelihood of a major (minor) problem (or diagnostic precision for that matter):*

(i) always provide the minor treatment if $h \in [0, h_L^{\mathrm{u}}]$;
(ii) follow the diagnosis if $h \in (h_L^{\mathrm{u}}, h_L^{\mathrm{o}}]$; and
(iii) always provide the major treatment if $h \in (h_L^{\mathrm{o}}, 1]$.

Define $\mathbf{P}^{\mathrm{o}} := (\bar{p}^{\mathrm{o}}, \underline{p}^{\mathrm{o}})$, $\mathbf{P}^{\mathrm{u}} := (\bar{p}^{\mathrm{u}}, \underline{p}^{\mathrm{u}})$, and $\mathbf{P}_i^{\mathrm{e}} := (\bar{p}_i^{\mathrm{e}}, \underline{p}_i^{\mathrm{e}})$ (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.

4.1.2. High-ability expert type

The pricing decision of 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 $\mathbf{P}_H^{\mathrm{e}}$.*

Proof. Follows from a straightforward comparison of expression (7) and expressions (3) and (6) together with 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 because the expert credibly commits to treating customers honestly, thereby maximizing customers' expected gross valuation.

4.1.3. Low-ability expert type

Note first that because the expert can fully extract customer surplus, the expert is interested in maximizing customers' expected gross valuation. As a consequence, we have that

$$\pi^{\mathrm{u}} \lesseqgtr \pi_L^{\mathrm{e}} \Leftrightarrow h \gtreqless h_L^{\mathrm{u}} \tag{12}$$

and

$$\pi^{\mathrm{o}} \lesseqgtr \pi_L^{\mathrm{e}} \Leftrightarrow h \lesseqgtr h_L^{\mathrm{o}} \tag{13}$$

We state the following proposition:

Proposition 2. *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:*

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

Proof. Given the comparison in expression (12) and the fact that $h_L^{\mathrm{u}} \leq h_L^{\mathrm{o}}$, it follows that $\mathbf{P}^{\mathrm{u}}$ is the optimal price-setting choice for any $h \in \left[0, h_L^{\mathrm{u}}\right]$. Together with the comparison in expression (13), the remaining cases can be derived in a similar fashion. □

Note that this benchmark result is in line with previous contributions (see, for example, Dai and Singh, 2020). Fig. 2 illustrates the pricing and treatment decisions by the low-ability expert type. As pointed out, it can be optimal (and efficient) to always choose a single kind of treatment depending on the probability of a major problem and diagnostic quality.[29]

We now turn to the case with unobservable expert types.

[29] This is related to a similar result in Bester and Dahm (2018). There, if the diagnosis cost is too high, it is optimal to implement a treatment without a diagnosis.

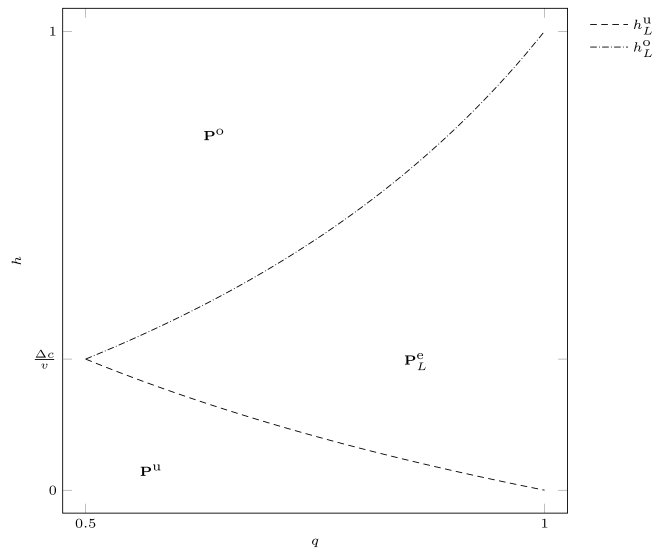

Fig. 2. Pricing of an observable low-ability expert type.

4.2. *Unobservable types*

In this part, we first present general features of the equilibrium outcomes in our setup. We then derive the equilibria and discuss two approaches to equilibrium selection.

4.2.1. *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 equilibrium by posting a certain price menu, the other type could easily mimic this offer and make the same strictly higher profit. Because ability does not directly affect profits, both types make the same profit as long as they charge the same prices. □

There are equilibria in which different expert types post the same price 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 along the equilibrium path, such that payoffs are the same. 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 exists an outcome-equivalent equilibrium without a separation in prices.*

Thus, we focus on pure-strategy equilibria with price pooling. Among those, we focus on the equilibria that yield the highest profits.[30]

4.2.2. *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) type-dependent-treatment recommendations. The prices and profits for the first two scenarios are the same as in Section 4.1 (see expressions (1)–(6)).

We start by defining the first class of equilibria:

Definition 1 (*Major-treatment Equilibria*)**.** We call perfect Bayesian equilibria major-treatment equilibria (with price pooling) if the following holds:

[30] 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. Note that constraining off-equilibrium beliefs may rule out some equilibria. In that sense, customers who do not update their beliefs, for example, may have a positive externality because they may destabilize some inefficient equilibria.

- Both expert types choose the price vector $\mathbf{P}^{\mathrm{o}}$.
- Both expert types always recommend and perform the major treatment.
- The low-ability expert type has the following beliefs (Bayesian updating):

$$\bar{\mu} = \frac{hq}{hq + (1-h)(1-q)} \text{ and } \underline{\mu} = \frac{(1-h)q}{(1-h)q + h(1-q)}.$$

- On the equilibrium path, customers' beliefs equal $\mu(\mathbf{P}^{\mathrm{o}}) = x$, and customers always visit the expert.

Next, we define the second class of equilibria:

Definition 2 (*Minor-treatment Equilibria*)**.** We call perfect Bayesian equilibria minor-treatment equilibria (with price pooling) if the following holds:

- 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 the following beliefs (Bayesian updating):

$$\bar{\mu} = \frac{hq}{hq + (1-h)(1-q)} \text{ and } \underline{\mu} = \frac{(1-h)q}{(1-h)q + h(1-q)}.$$

- On the equilibrium path, customers' beliefs equal $\mu(\mathbf{P}^{\mathrm{u}}) = x$, and customers always visit the expert.

Let us briefly comment on the structure of these equilibria. In the major-treatment equilibria with price pooling, both expert types choose their price vectors such that they always optimally recommend the major treatment, independent of the customer's problem. Analogously, in the minor-treatment equilibria with price pooling, both types choose their price vectors such that it is always optimal to recommend the minor treatment. An expert of low ability believes he has received the correct diagnosis with a probability that is equal to his Bayesian posterior, given the ex ante probability of either type of problem and the accuracy of his diagnosis. Given that both expert types set identical prices, that is, no information concerning expert types is conveyed, customers believe they are facing a certain expert type with the ex ante probability that this type is chosen by nature whenever the major-treatment (or minor-treatment) price vector is observed.

Note that those definitions do not specify off-path beliefs and actions beyond how they are specified in the definition of perfect Bayesian Nash equilibria. The latter implies that if customers observe an (off-path) price vector, they will expect the expert to recommend the major (minor) treatment if the profit margin for the major (minor) treatment is larger, independent of the expert's type. Thus, the customers' beliefs about the expert's type in that case can be anywhere between zero and one. Customers' off-equilibrium beliefs are also not restricted for off-path equal-markup price vectors with a lower profit margin than the profit margin along the equilibrium path because in such a case, no expert would have an incentive to deviate. Off-path beliefs about the expert's type are only (potentially) constrained for equal-markup prices with a higher profit margin to ensure that no expert would want to deviate. 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 customers 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 and is following his diagnosis. Given sufficiently weak beliefs, the high-ability type cannot make a higher profit from deviating to equal-markup prices because the customers' expected surplus does not increase compared to a situation in which they always receive the major or minor treatment. To be consistent with different tie-breaking assumptions, we specify the constraints on off-path beliefs later, together with the relevant propositions.

We now turn to type-dependent-treatment equilibria, for which an analogous reasoning with regard to off-path beliefs and actions applies. In these equilibria, each type of expert may choose to either condition the treatment on the diagnosis or to always perform one of the two treatments, with at least one expert type following his diagnosis. To get the intuition, consider the scenario in which both types of expert follow their diagnosis (subscript dd). In this case, prices for equal markups are given by

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

and

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

The profit for each type equals

$$\begin{aligned}\pi^{\mathrm{e}}_{dd} &= (1 - h + hq - hqx + hx)\, v - \underline{c} \\ &- (1 - h + 2hq - 2hqx + 2hx - q + qx - x)\, \Delta c. \end{aligned} \tag{14}$$

A comparison of profits in the different scenarios reveals that

$$\pi^{\mathrm{u}} \lesseqqgtr \pi^{\mathrm{e}}_{dd} \Leftrightarrow h \gtreqqless \frac{(1 - q + qx - x)\Delta c}{(q - qx + x)v + (1 - 2q + 2qx - 2x)\Delta c} =:\ h^{\mathrm{u}}_{dd} \tag{15}$$

and

$$\pi^{\mathrm{o}} \lesseqqgtr \pi^{\mathrm{e}}_{dd} \Leftrightarrow h \lesseqqgtr \frac{(q - qx + x)\Delta c}{(1 - q + qx - x)v - (1 - 2q + 2qx - 2x)\Delta c} =:\ h^{\mathrm{o}}_{dd}. \tag{16}$$

It holds that

$$\frac{\partial h^{\mathrm{u}}_{dd}}{\partial q}, \frac{\partial h^{\mathrm{u}}_{dd}}{\partial x} < 0 \tag{17}$$

and

$$\frac{\partial h^{\mathrm{o}}_{dd}}{\partial q}, \frac{\partial h^{\mathrm{o}}_{dd}}{\partial x} > 0. \tag{18}$$

Thus, both probabilities have a very similar effect on the two thresholds. Under equal-markup pricing, efficiency is affected by diagnostic quality. Because the expected gain from interaction is always zero for the customer, however, it does not make any difference for the customer from an ex ante point of view 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. In the scenarios with only major-treatment/minor-treatment recommendations, the thresholds are unaffected by either of the two probabilities because the two expert types do not differ in their recommendations.

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

$$\begin{aligned}\bar{p}^{\mathrm{e}}_{jk} = \underline{p}^{\mathrm{e}}_{jk} + \Delta c = x\left(\mathbb{1}_{j=o} v + \mathbb{1}_{j=u}((1-h)v + \Delta c) + \mathbb{1}_{j=d}(v + (1-h)\Delta c)\right) \\ + (1-x)\left(\mathbb{1}_{k=o} v + \mathbb{1}_{k=u}((1-h)v + \Delta c)\right. \\ \left.+\mathbb{1}_{k=d}(v(1-h(1-q)) + ((1-h)q + h(1-q))\Delta c)\right),\end{aligned} \tag{19}$$

where $\mathbb{1}$ is the indicator function.

The profits are $\pi^{\mathrm{e}}_{jk} = \bar{p}^{\mathrm{e}}_{jk} - \bar{c}$.[31] These profits are larger than a low-ability expert type's profit and smaller than a high-ability expert type's profit when types are observable and equal-markup prices are optimal. Thus, the lack of observability produces a positive externality of the high-ability type on the low-ability type and a negative externality vice versa.

Given the above prices, we can define the type-dependent-treatment equilibria:

Definition 3 (*Type-dependent-treatment Equilibria*)**.** We call perfect Bayesian equilibria type-dependent-treatment equilibria (with price pooling) if the following holds:

- Both expert types choose the price vector $\mathbf{P}^{\mathrm{e}}_{jk}$.
- Expert types either follow their diagnosis or always perform one kind of treatment ($j \in \{d, o, u\}$ and $k \in \{d, o, u\}$), with at least one expert type following his diagnosis.
- The low-ability expert type has the following beliefs (Bayesian updating):

$$\bar{\mu} = \frac{hq}{hq + (1-h)(1-q)} \text{ and } \underline{\mu} = \frac{(1-h)q}{(1-h)q + h(1-q)}.$$

- On the equilibrium path, customers' beliefs equal $\mu(\mathbf{P}^{\mathrm{e}}_{jk}) = x$, and customers always visit the expert.

Given identical markups, any treatment recommendation is equally profitable for an expert — independent of his type. For example, if, in equilibrium, the high-ability expert always follows the diagnosis and the low-ability expert always recommends the major treatment, the prices are $\bar{p}^{\mathrm{e}}_{do} = \underline{p}^{\mathrm{e}}_{do} + \Delta c = x(v + (1-h)\Delta c) + (1-x)v = v + x(1-h)\Delta c$. As in the previously defined equilibria, an expert of low ability believes he has received the correct diagnosis with a probability that is equal to his Bayesian posterior, given the ex ante probability of either type of problem and the accuracy of his diagnosis. Again, no information concerning expert types is revealed through the price setting, which means that customers believe that they are facing a certain expert type with this type's (ex ante) probability of being selected by nature whenever the equal-markup price vector is posted by the expert. Even though no such information is revealed through the price setting, the expert's treatment may depend on his type.

With regard to customers' off-equilibrium beliefs, prices that 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. Again, there is no restriction with respect to the beliefs when customers observe prices that are lower than those charged along the equilibrium path.

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

Proposition 3. *The existence of equilibria with price pooling is characterized as follows:*

(i) There exist minor-treatment equilibria if and only if $h \in [0, \Delta c/v]$*;*
(ii) there exist major-treatment equilibria if and only if $h \in [\Delta c/v, 1]$*;*
(iii) there exist type-dependent-treatment equilibria for all $h \in [0, 1]$.

[31] Note that our results do not depend on the assumption that the low-ability expert type's diagnosis is correct with a probability q that does not depend on the underlying problem. If we allow for that and let $\bar{q}$ and $\underline{q}$ be the according probabilities, we have $\bar{p}^{\mathrm{e}}_{jk} = \underline{p}^{\mathrm{e}}_{jk} + \Delta c = x\left(\mathbb{1}_{j=o} v + \mathbb{1}_{j=u}((1-h)v + \Delta c) + \mathbb{1}_{j=d}(v + (1-h)\Delta c)\right) + (1-x)\left(\mathbb{1}_{k=o} v + \mathbb{1}_{k=u}((1-h)v + \Delta c) + \mathbb{1}_{k=d}(v(1-h(1-\bar{q})) + ((1-h)\underline{q} + h(1-\bar{q}))\Delta c)\right)$.

Proof. This proof is based on the arguments that were used for Definition 2. First, both expert types do not find it profitable to lower their prices because, according to customers' off-equilibrium beliefs, this would only lead to lower profits. Second, deviating to higher prices is not profitable for the expert either if the following two conditions are met: (i) posting a price vector with unequal markups followed by the expert recommending the treatment with the higher markup is not viable; and (ii) customers have sufficiently bad beliefs (that is, believe it is sufficiently unlikely that they are facing a high-ability expert type following his diagnosis) in the case of an off-path equal-markup price vector.[32] Posting a price vector that commits the expert to always recommending the major treatment leads to profits of at most $v - \bar{c}$. Analogously, posting a price vector that commits the expert to always recommending the minor treatment leads to profits of at most $(1-h)v - \underline{c}$. Comparing those two profits determines the threshold for the minor-treatment and major-treatment equilibria. If customers believe that experts in the case of an equal-markup price vector would always recommend one treatment, an equal-markup price vector with a higher profit margin is not a profitable deviation either. Type-dependent-treatment equilibria of the following kind exist everywhere. Expert types recommend the treatment they would recommend in the observable-type benchmark and post prices according to Eq. (19). Price vectors committing to always recommending one treatment are clearly less profitable because customers' maximal willingness to pay is lower than for the observable-type benchmark behavior. Equal-markup price vectors with a lower profit margin are clearly not profitable, and those with a higher profit margin will lead to customers not visiting the expert as long as the customers' beliefs that the expert has a high ability (and expert types recommend treatments as in the observable-type benchmark) are not larger than x. □

Thus, we can conclude that there exist several different types of type-dependent-treatment equilibria, some of which appear to be implausible. The usual equilibrium selection criteria do not have any bite here because the expert's type does not affect his profits directly, but only indirectly via equilibrium prices that depend on customers' beliefs. We continue with a further analysis of type-dependent-treatment equilibria by imposing two assumptions on equilibrium selection that are relevant in different contexts.

4.2.3. Equilibrium selection: 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 in which experts maximize their customers' expected utility. For consistency, we apply those tie-breaking rules both on and off the equilibrium path.

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 (for example, when presenting diagnoses outcomes in court).[33]

For the analysis to follow, we can use the thresholds defined in expressions (10), (11), (15), and (16). Selecting the equilibria from Proposition 3 in which the indifferent expert type follows his diagnosis, we describe the set of equilibria in this case in the following proposition:

Proposition 4. *The existence of equilibria with price pooling when indifferent expert types follow their diagnosis is characterized as follows:*

(i) There exist minor-treatment equilibria if and only if $h \in [0, h_L^{\mathrm{u}}]$*;*
(ii) there exist type-dependent-treatment equilibria in which each expert type follows his diagnosis if and only if $h \in [h_{dd}^{\mathrm{u}}, h_{dd}^{\mathrm{o}}]$*; and*
(iii) there exist major-treatment equilibria if and only if $h \in [h_L^{\mathrm{o}}, 1]$.

Proof. Assume that the customers' beliefs in an off-path equal-markup price vector are that the expert has a high ability with probability zero and that the expert behaves according to the tie-breaking rule. The customers' beliefs in an off-path price vector with unequal markups are that the expert has a high ability with a probability (weakly) between zero and one and that the expert always recommends the treatment with the higher profit margin.

If there exist major-treatment equilibria, the expert chooses the price vector $\mathbf{P}^{\mathrm{o}}$, gets a profit of π^{o} (see Eq. (3)) in equilibrium, and has no incentive to increase prices given the beliefs of customers. Deviating to equal-markup prices allows the expert to obtain

$$\pi_{dd}^{\mathrm{e}}(\mu') = (1 - h + hq - hq\mu' + h\mu')v - \underline{c} - (1 - h + 2hq - 2hq\mu' + 2h\mu' - q + q\mu' - \mu')\Delta c. \tag{20}$$

Deviating to the undertreatment price vector $\mathbf{P}^{\mathrm{u}}$ gives the expert a profit of π^{u} (see Eq. (6)). The conditions of the existence of major-treatment equilibria are that $\pi^{\mathrm{o}}(\mu = x) \geq \pi_{dd}^{\mathrm{e}}(\mu')$ and $\pi^{\mathrm{o}}(\mu = x) \geq \pi^{\mathrm{u}}$. It is easy to check that the first condition is binding. Thus, we get

$$\pi^{\mathrm{o}}(\mu = x) \lesseqgtr \pi_{dd}^{\mathrm{e}}(\mu') \Leftrightarrow h \lesseqgtr \frac{(\mu' + q - \mu' q)\Delta c}{(1 + \mu' q - \mu' - q)v - (1 - 2\mu' - 2q + 2\mu' q)\Delta c}. \tag{21}$$

[32] To derive the boundaries, we use customers holding a belief of one that they will receive a type-independent treatment from an expert posting an off-equilibrium equal-markup price vector. In general, however, equilibrium behavior can be supported by a larger set of beliefs. In the following section, we restrict off-equilibrium beliefs (in line with equilibrium behavior), and thus, derive different boundaries.

[33] Note that the equilibria derived in this section coincide with the equilibria if every expert thinks he has a sufficiently high diagnostic ability to make his treatment dependent on his diagnosis as if types were observable. Moreover, note that following their diagnosis may come with another benefit that we abstract away from in our analysis: a low-ability expert might learn and improve his ability over time.

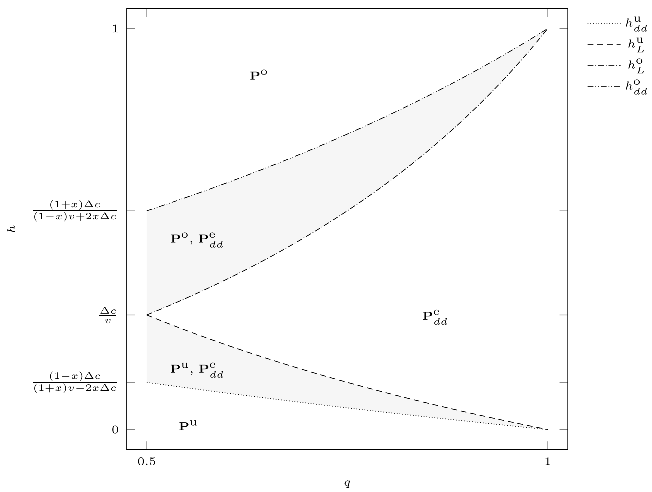

Fig. 3. Equilibrium pricing when an indifferent expert type follows his diagnosis.

Note that if $\mu' = 0$, the threshold in the above expression is equal to h^{o}_{L}.

Similarly, if there exist minor-treatment equilibria, the expert chooses the price vector $\mathbf{P}^{u}$ and gets a profit of π^{u} (see Eq. (6)) in equilibrium. The conditions of the existence of minor-treatment equilibria are that $\pi^{\mathrm{u}}(\mu = x) \geq \pi^{\mathrm{e}}_{dd}(\mu')$ and $\pi^{\mathrm{u}}(\mu = x) \geq \pi^{\mathrm{o}}$. Because the first condition is binding, we get

$$\pi^{\mathrm{u}}(\mu = x) \lesseqqgtr \pi^{\mathrm{e}}_{dd}(\mu') \Leftrightarrow h \gtreqqless \frac{(1-\mu'-q+\mu' q)\Delta c}{(\mu'+q-\mu' q)v + (1-2\mu'-2q+2\mu' q)\Delta c}. \tag{22}$$

Note that the threshold in the above expression equals h^{u}_{L} if $\mu' = 0$.

Together with the comparisons in Eqs. (16) and (15), we can summarize the analysis above to obtain the equilibria in the proposition. □

Because $h^{\mathrm{u}}_{dd} < h^{\mathrm{u}}_{L}$ and $h^{\mathrm{o}}_{dd} > h^{\mathrm{o}}_{L}$, there are multiple equilibria for some values of the probability of the major problem but not for others.

Because being pooled with the high-ability type makes equal-markup prices attractive for the low-ability type in a wider parameter range than when types are observable, the low-ability type may overly rely on his signal. Moreover, the presence of the low-ability type makes equal-markup prices less attractive for the high-ability type and may not let him use the information of his signal enough.

Fig. 3 illustrates the existence of the different equilibria. In all figures, the size of the gray areas (that is, combinations of q and h or x) 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 are facing a low-ability expert type with certainty.

Indifferent expert type maximizes customers' expected utility. If both expert types maximize their customers' expected utility when types are indifferent, after setting the prices, experts behave as if their type were observable, that is, 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 minor treatment, depending on which will lead to a higher expected utility for customers. Again taking the respective equilibria from Proposition 3, the set of equilibria in this case is described in the following proposition:

Proposition 5. *The existence of equilibria with price pooling when indifferent expert types maximize customers' expected utility is characterized as follows:*

(i) *There exist minor-treatment equilibria if and only if $h \in [0, h^{\mathrm{u}}_{L}]$;*
(ii) *there exist major-treatment equilibria if and only if $h \in [h^{\mathrm{o}}_{L}, 1]$;*
(iii) *there exist the following type-dependent-treatment equilibria for all $h \in [0,1]$: the high-ability expert type always follows his diagnosis; the low-ability expert type follows his diagnosis if $h \in (h^{\mathrm{u}}_{L}, h^{\mathrm{o}}_{L}]$, always performs the minor treatment if $h \in [0, h^{\mathrm{u}}_{L}]$, and always performs the major treatment if $h \in (h^{\mathrm{o}}_{L}, 1]$.*

Proof. The proof is analogous to that of Proposition 4 and is thus omitted here. □

Fig. 4 illustrates the existence of the different equilibria.

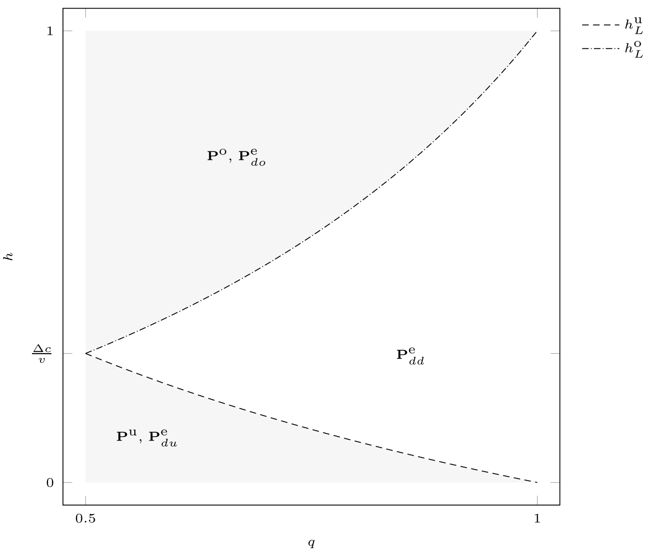

Fig. 4. Equilibrium pricing when an indifferent expert type maximizes customers' expected utility.

5. Discussion

In this section, we discuss the welfare properties of the equilibria considered and analyze how better diagnostic outcomes impact the efficiency of these equilibria. Moreover, we show that our results are robust to various forms of diagnosis effort and competition, and that even small fines and warranties may break some inefficient equilibria, which may make them useful policy instruments. Throughout this section, we assume that one of the tie-breaking rules discussed in the previous section applies.

5.1. Efficiency

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

Proposition 6. *Consider the type-dependent-treatment equilibria in which the high-ability expert type always follows his diagnosis and the low-ability expert type follows his diagnosis if $h \in (h_L^{\mathrm{u}}, h_L^{\mathrm{o}}]$, performs the minor treatment if $h \in [0, h_L^{\mathrm{u}}]$, and performs the major treatment if $h \in (h_L^{\mathrm{o}}, 1]$. These equilibria are efficient. The maximum prices and the resulting profits are weakly higher than those in any other type-dependent-treatment equilibrium with price pooling.*

An immediate conclusion from Proposition 6 is that, depending on the scope of diagnostic ability and the likelihood that a major problem occurs, efficiency is thus crucially affected by the tie-breaking rule. More precisely, the rules compare as follows:

Corollary 2. *For $h \in [0, h_L^{\mathrm{u}}] \bigcup (h_L^{\mathrm{o}}, 1]$, there does not exist an efficient equilibrium when indifferent expert types follow their diagnosis; there exists an efficient equilibrium when indifferent expert types maximize customers' expected utility. For $h \in (h_L^{\mathrm{u}}, h_L^{\mathrm{o}}]$, either tie-breaking rule implements the efficient equilibrium.*

Fig. 5 summarizes the existence of the different equilibria under the two tie-breaking rules, where the boundaries are the same as in Fig. 3. These boundaries divide the permissible combinations of the diagnostic precision and the likelihood of the major problem in five regions. The regions feature different pooling equilibria that, in turn, are relevant for the evaluation of a change in diagnostic performance (see next section). For each of these regions, Fig. 5 characterizes the efficient equilibrium pricing, where efficient equilibrium price vectors are boxed. As can be seen from the figure and as shown in the analysis, an efficient pooling equilibrium always exists. Whenever the low-ability type's diagnostic outcome is relatively precise or the likelihood that a major problem occurs is of intermediate value, both tie-breaking rules yield the same efficient outcome. In this case, following the sufficiently precise diagnosis maximizes customers' utility. For the remaining parameter combinations, the only efficient equilibria are those in which the high-ability type follows his diagnosis and the low-ability ability always performs the major treatment (when the major problem

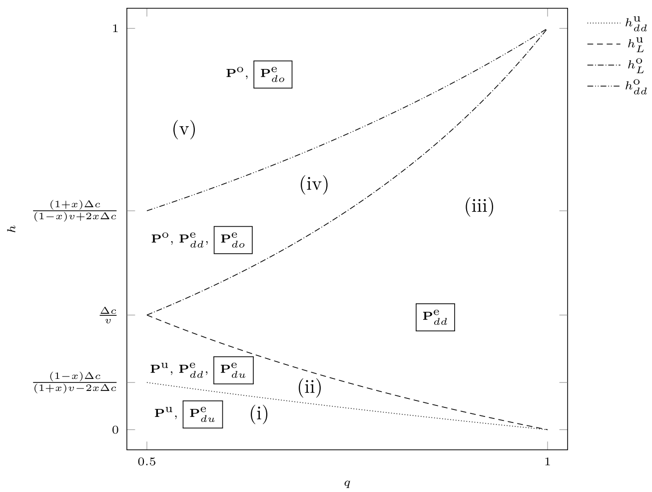

Fig. 5. Summary of equilibrium pricing (under either tie-breaking rule) and efficient pricing (boxed).

is very likely) or the minor treatment (when the minor problem is very likely). Thus, a low-ability type following his diagnosis over-uses his diagnostic information in this case. The most inefficient outcomes are those where both expert types always perform the major treatment or the minor treatment. Here, the high-ability expert under-uses his diagnostic information.

We can use this insight to analyze the effects of improvements in diagnostic quality.

5.2. Better diagnostic performance

From a policy perspective, the question of whether better diagnostic performance improves the market outcome (that is, efficiency and social welfare) is very important — especially when such an endeavor involves substantial costs. An improvement can come in two forms: First, the low-ability expert type may become better at supplying an accurate diagnosis (that is, q increases). Second, the probability that an expert is a high type may increase (that is, x increases). We discuss each improvement separately.

Before doing so, let us point out the general idea behind the comparative statics analysis that follows. Depending on the parameter combinations, (i) efficient and inefficient equilibria may coexist, and so may (ii) equilibria whose efficiency is affected by neither of the two possible improvements (that is, major-treatment and minor-treatment equilibria) and those whose efficiency may be affected by the two parameters (that is, type-dependent-treatment equilibria). As a consequence, an improvement in diagnostic performance (irrespective of the source) depends on the type of equilibrium played.

5.2.1. Increase in diagnostic precision

The effect of an increase in the diagnostic precision crucially depends on the ex ante probability of customers with a major problem and the equilibrium that is played. With regard to the type-dependent-treatment equilibria, the tie-breaking rule is essential. As long as the low-ability type follows his diagnosis, a more precise diagnosis leads to higher social welfare because the low-ability expert provides the appropriate treatment for customers more often. By contrast, if the low-ability type always performs the major treatment or the minor treatment, a change in diagnostic precision has no impact. This is also true for the major-treatment equilibria and the minor-treatment equilibria in which both types always provide either treatment.

Given these considerations, we can now analyze the effects of a change in the diagnostic precision of the low-ability type in and across the five different regions in Fig. 5. As a first observation, we have that changes in the low-ability expert's diagnostic precision have no impact in regions (i) and (v) irrespective of which equilibrium expert types coordinate on. Furthermore, if expert types coordinate on the minor-treatment/major-treatment equilibria or the type-dependent-treatment equilibria in which the low-ability type does not follow his diagnosis in regions (ii) and (iv), changes in diagnostic precision have no effect either. By contrast, an increase in diagnostic precision results in higher welfare in regions (ii)–(iv) whenever expert types coordinate on the type-dependent-treatment equilibria in which the low-ability type follows his diagnosis. Note, however, that in regions (ii) and (iv), this improvement is only marginal because the efficient equilibria require the low-ability type to always perform the minor treatment or the major treatment. In region (iii), that is, when the low-ability type's diagnostic ability is sufficiently large for him to follow his signal under either tie-breaking rule, a further improvement in his diagnostic ability guarantees a welfare increase.[34]

We can thus summarize our findings in the following straightforward proposition:

[34] The threshold for q is derived by solving $h \in (h^{u}_{L}, h^{o}_{L})$ for q.

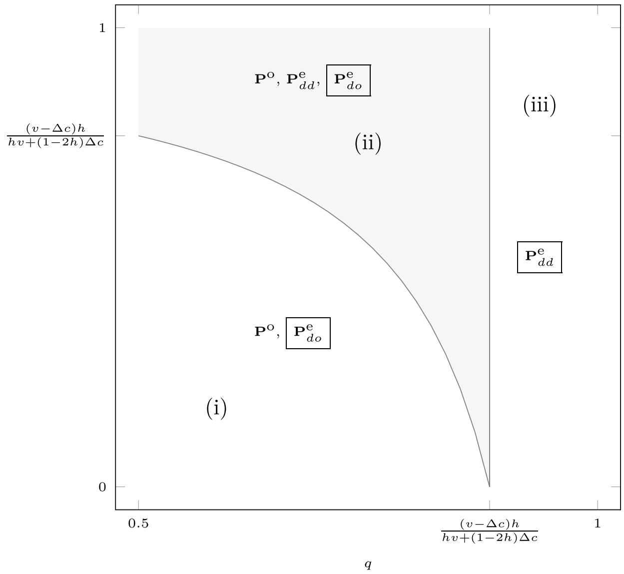

Fig. 6. Equilibrium pricing (under either tie-breaking rule) and efficient pricing (boxed) for combinations of q and x (for $h > \Delta c/v$).

Proposition 7. *When both types do not choose an equal-markup price vector for $h \in (h^{u}_{dd}, h^{u}_{L})$ or $h \in (h^{o}_{L}, h^{o}_{dd})$, better diagnostic abilities of the low-ability expert type have no effect on efficiency. If $q > (\max\{hv, \Delta c\} - h\Delta c)/(hv + (1-2h)\Delta c)$, however, such an improvement increases efficiency.*

Consider now scenarios in which the change of diagnostic precision of the low-ability type means that another region is reached. Now, if the expert types and customers continue to coordinate on an equilibrium that exists in both regions, the effect of such a change is as described above. An additional effect arises if expert types coordinate on different types of equilibria in the two regions. Consider the transition from region (ii) to region (iii) in Fig. 5 due to an increase in diagnostic precision. If expert types coordinate on the most inefficient minor-treatment equilibria in region (ii), there is a jump in welfare once they reach region (iii) because the inefficient minor-treatment equilibrium ceases to exist. Thus, a sufficiently large increase in the diagnostic precision of the low-ability type guarantees an improvement in welfare.

We can thus summarize that better diagnostic abilities do not necessarily lead to higher efficiency. Naturally, if improving diagnostic abilities comes at any cost, this may decrease welfare. If the diagnostic ability of the low-ability type becomes large enough, however, such that major-treatment or minor-treatment equilibria no longer exist, an increase in that ability is efficiency enhancing. Consequently, a sufficiently strong increase in the diagnostic ability of the low-ability type can robustly increase welfare.

5.2.2. Increase in probability of high-ability expert

Note first that, in contrast to a change in diagnostic precision, a change in the probability of a high-ability expert affects welfare in the type-dependent-treatment equilibria in which the low-ability type always performs the major treatment or the minor treatment. Fig. 6 illustrates the existence of different equilibria depending on the diagnostic precision and the probability of a high-ability expert type (given a relatively high probability that a major problem occurs).

An increase in the probability of a high-ability expert increases efficiency in region (iii) (where diagnostic abilities of the low-ability type are high). In this region, only efficient type-dependent-treatment equilibria in which both experts follow their diagnosis exist. If the low-ability type's diagnosis is less reliable (regions (i) and (ii)) an increase in the probability of a high-ability expert type leads to an increase in welfare whenever expert types coordinate on a type-dependent-treatment equilibrium. In the major-treatment equilibria that also exist in these regions, a change in the probability of a high-ability expert does not affect welfare.

We can thus state the following result:

Proposition 8. *If expert types coordinate on a major-treatment or minor-treatment equilibrium, a higher probability of a high-ability expert type does not increase welfare. If they coordinate on a type-dependent equilibrium, a higher probability of a high-ability expert type increases welfare.*

We point out that neither increasing the probability of the high-ability type nor increasing the diagnostic precision of the low-ability type decreases efficiency if there is no direct cost of doing so. If increasing either is costly (which we do not model explicitly), a policymaker should not make use of this option if players coordinate on the major-treatment or the minor-treatment equilibria, unless in combination with other policies that have the potential to get rid of those equilibria, such as price regulation or increasing transparency. A further important exception can be explained by referring to Fig. 6. The figure is a counterpart to Fig. 5. In contrast to that figure, Fig. 6 considers combinations of the share of a high-ability expert type and the low-ability type's diagnostic precision for a given (relatively) high likelihood of the major problem. The boundaries that define the three different regions can be derived from h^o_L and h^o_{dd}. Note first that h^o_L is independent of x (see Expression (11)), which gives the vertical line in the figure. The second boundary can be derived from setting $h = h^o_{dd}$ and solving for x.[35] Now, as the figure illustrates, if the policymaker increases the diagnostic precision of the low-ability type not only marginally but by sufficiently much, those equilibria do not exist anymore. By contrast, increasing the probability of a high-ability type to a value smaller than one does not have such an effect.

5.3. Effort

In our basic model, we have assumed that diagnostic ability is exogenous. Our results, however, extend to several important situations in which the expert can exert effort to influence the precision of a diagnosis. If effort is not observable or is too costly, the expert does not have an incentive to exert any effort in the absence of an additional motive, such as sufficiently strong altruism or another expert checking the diagnosis. Our exogenous diagnostic ability could be interpreted as the exogenous baseline diagnostic ability (for exerting no effort) in this case.[36] We thus have:

Proposition 9. *Assume that the (low-ability type) expert can exert costly effort $e \geq 0$ to improve the signal accuracy to $q + e$. If effort is not observable, the expert chooses $e = 0$.*

This means that in settings in which ex ante investments by experts are important, a policymaker should try to make investments or abilities visible (for example, through certification).

5.4. Competition

So far, we have assumed that the expert is a monopolist. This section demonstrates that our results are robust to competition. There is a shift of surplus from experts to customers, but the equilibrium treatment strategies continue to exist, and hence, efficiency remains unchanged. In the following, we consider a situation in which at least two experts compete à la Bertrand.

When the experts' types are observable, we have to consider three different cases. First, if there are at least two experts with a high diagnostic ability, at least two high-ability experts charge prices as in Section 4.1, the only difference being that the prices of both treatments are reduced by their expected profit as given in Section 4.1. Customers only visit those experts, and those experts follow their diagnoses. Other experts charge prices that are not attractive for customers. Thus, all experts make zero profit, and no one has an incentive to deviate.

Second, if all experts have a low ability, at least two of them charge prices as in Section 4.1, the only difference being that the prices of both treatments are reduced by their expected profit as given in Section 4.1. Customers only visit those experts, and those experts employ the treatment strategy of Section 4.1. Other experts charge prices that are not attractive for customers. Again, all experts make zero profits, and no one has an incentive to deviate.

Third, if there is exactly one expert with a high ability, at least one low-ability expert charges prices as in Section 4.1, the only difference being that the prices of both treatments are reduced by the low-ability type's expected profit given in Section 4.1. The high-ability expert reduces his prices from Section 4.1 by the same amount, such that customers are indifferent between visiting him and the low-ability expert. In equilibrium, however, all customers visit the high-ability expert who follows his diagnosis. All other experts charge prices that are not attractive for customers. Thus, all low-ability experts make zero profits, and no one has an incentive to deviate. The high-ability expert makes positive profits, but does not have an incentive to deviate either.

We can thus summarize experts' treatment decisions for the case with observable types as follows:

Proposition 10. *Assume expert types are observable. Given any parameter values, if an expert's treatment strategy is part of an equilibrium in the monopoly case, it is also part of an equilibrium in the competition case.*

When the experts' types are not observable, low-ability experts can – as in the monopoly case – imitate a high-ability expert at no cost because they have the same profit function.[37] Thus, all equilibria derived in Section 4.2 have a treatment-equivalent equilibrium, the only difference being that the prices of both treatments are reduced by the experts' expected profit in the corresponding equilibrium as given in Section 4.1. At least two experts charge those prices, customers only visit those experts, and other experts charge unattractive prices. Experts make zero profit, and no one has an incentive to deviate. If q is large and h is intermediate, however, there are additional type-dependent-treatment equilibria in which experts make positive profits as long as they charge only moderate prices: If there is no profitable major-treatment or minor-treatment vector that would also appeal to customers, customers may also hold the belief that a deviating expert posting an equal-markup price vector provides a diagnosis-independent treatment, which is not attractive to customers. If prices were too high, an expert could deviate by posting a major-treatment and minor-treatment price vector. This means that the threat of major-treatment and minor-treatment price vectors can provide commitment against high prices.

We can summarize our analysis of competition with unobservable types analogously to Proposition 3[38]:

---

[35] As such, regions (i), (ii), and (iii) in the figure correspond to regions (v), (iv), and (iii) for $h > \Delta c/v$ in Fig. 5.

[36] Recall that our results do not depend on the high-ability type having a perfect ability. If effort is observable but the expert type cannot be inferred from the effort choice, our exogenously given diagnostic abilities can be interpreted as endogenous total diagnostic abilities.

[37] Hence, it also does not matter whether experts can observe each other's types.

[38] The results of Propositions 4 and 5 extend analogously.

Proposition 11. *Assume expert types are not observable. In the case of Bertrand competition with at least two experts, the existence of equilibria with price pooling is characterized as follows:*

(i) for $h \in [0, \Delta c/v]$, there exist equilibria with minor-treatment price vectors;
(ii) for $h \in [\Delta c/v, 1]$, there exist equilibria with major-treatment price vectors; and
(iii) for $h \in [0, 1]$, there exist equilibria with equal-markup price vectors.

Thus, because the treatments under competition are the same as with a monopolistic expert, the results with regard to efficiency remain unchanged.

5.5. Fines and warranties

In this section, we assume that the expert is liable and has to pay a fine $f > 0$ whenever the treatment is insufficient. A compensation that the expert has to pay to the customer if the treatment is insufficient (warranty) would work in the same way.[39]

In the case of observable types, the high-ability type does not change his strategy. The low-ability ability type compares $\pi^{\mathrm{o}}, \pi^{\mathrm{u}} - hf$, and $\pi^{\mathrm{e}} - h(1-q)f$. If a fine affects a low-ability type's recommendation strategy, it will only decrease efficiency because his privately optimal behavior was also efficient.

Now we consider the case of unobservable types:

Proposition 12. *If there is a fine f for insufficient treatment, there are neither major-treatment nor minor-treatment equilibria.*

Proof. Suppose there exists a major-treatment equilibrium in which expert types charge the price vector $(\bar{p}^{\mathrm{o}}, \underline{p}^{\mathrm{o}})$, with $\bar{p}^{\mathrm{o}} \geq \underline{p}^{\mathrm{o}} + \bar{c} - \underline{c}$ (such that both expert types always recommend the major treatment) and thus earn $\bar{p} - \bar{c}$. Then, a price vector $(\bar{p}^{\mathrm{o}} - \varepsilon, \bar{p}^{\mathrm{o}} - \bar{c} + \underline{c} + 2h\varepsilon/(1-h))$ (with $\varepsilon > 0$ small) provides the high-ability expert type with strict incentives to recommend the appropriate treatment because the minor treatment leads to higher profits if and only if the problem is minor. Because his expected profits would be higher, a high-ability expert type would want to deviate to that price vector if customers still wanted to visit him. The same price vector lets the low-ability expert type always choose the major treatment because if he instead followed his signal, he would end up paying the fine too often, lowering his expected profits.[40] Customers are better off with this price vector because they would receive the appropriate treatment from a high-ability expert type (which means that they would only have to pay the (lower) minor-treatment price in some cases), and they would receive the major treatment from a low-ability expert, paying $\bar{p}^{\mathrm{o}} - \varepsilon$. Thus, they would still visit the expert, making a deviation by the high-ability expert profitable. Thus, no major-treatment equilibrium exists.

Similarly, suppose there exists a minor-treatment equilibrium in which expert types charge the price vector $(\bar{p}^{\mathrm{u}}, \underline{p}^{\mathrm{u}})$, with $\bar{p}^{\mathrm{u}} \leq \underline{p}^{\mathrm{u}} + \bar{c} - \underline{c} - f$ (such that both expert types always recommend the minor treatment) and thus earn $\underline{p}^{\mathrm{u}} - \underline{c} - hf$. Then, a price vector $(\underline{p}^{\mathrm{u}} + \bar{c} - \underline{c} + 2(1-h)\varepsilon/h - f, \underline{p}^{\mathrm{u}} - \varepsilon)$ (with $\varepsilon > 0$ small) provides the high-ability expert type with strict incentives to recommend the appropriate treatment because the minor treatment leads to higher profits if and only if the problem is minor. Because his expected profits would be higher, a high-ability expert type would want to deviate to that price vector if customers were still visiting him. The same price vector lets the low-ability expert type always choose the minor treatment because if he instead followed his signal, he would end up charging a low markup too often compared to the benefit of avoided fines, lowering his expected profits.[41] Customers are better off with this price vector because they would receive the appropriate treatment from a high-ability expert type (which means that they have their problem solved in all cases), and they would receive the minor treatment from a low-ability expert, paying the same price $\underline{p}^{\mathrm{u}}$ as in the equilibrium we supposed. Thus, they would still visit the expert, making a deviation by the high-ability expert profitable. Thus, no minor-treatment equilibrium exists. □

Now, consider type-dependent-treatment equilibria. There always exist price vectors that induce the high-ability expert type to follow his signal and induce the low-ability expert type to (i) always recommend the major treatment ($\underline{p} - \underline{c} \geq \bar{p} - \bar{c} \geq \underline{p} - \underline{c} - h(1-q)f/(h(1-q) + (1-h)q)$), (ii) always recommend the minor treatment ($\underline{p} - \underline{c} - hqf/(hq + (1-h)(1-q)) \geq \bar{p} - \bar{c} \geq \underline{p} - \underline{c} - f$), or (iii) always follow his signal ($\underline{p} - \underline{c} - h(1-q)f/(h(1-q) + (1-h)q) \geq \bar{p} - \bar{c} \geq \underline{p} - \underline{c} - hqf/(hq + (1-h)(1-q))$), with strict incentives when the inequalities are strict. Because customers' willingness to pay is maximal for efficient treatment recommendations, one can always induce an arbitrarily small fine which ensures that both expert types have a strict incentive to recommend efficiently (and this will constitute an equilibrium if the prices extract the customers' full surplus). This does not mean that there are only efficient equilibria: Suppose an inefficient type-dependent-treatment equilibrium is played in which both expert types follow their signal. Then, this equilibrium cannot be broken by a price vector that induces a diagnosis-independent treatment by the low-ability type, if

[39] Note that fines and compensations are similar to what the literature calls liability. In contrast to liability, however, the expert may (and, depending on parameters, sometimes will) provide an insufficient treatment. For efficient liability design in credence goods markets, see Chen et al. (2022).

[40] That is, compare a low-ability expert's expected profit of recommending a major treatment versus a minor treatment after observing a signal indicating a minor problem: $\bar{p}^{\mathrm{o}} - \varepsilon - \bar{c} > \bar{p}^{\mathrm{o}} - \bar{c} + \underline{c} + 2h\varepsilon/(1-h) - \underline{c} - (1-h)qf/(h(1-q) + (1-h)q)$ for ε sufficiently small. Thus, a low-ability expert prefers to recommend a major treatment even after observing a signal indicating a minor problem.

[41] That is, compare a low-ability expert's expected profit of recommending a major treatment versus a minor treatment after observing a signal indicating a major problem: $\underline{p}^{\mathrm{u}} - \underline{c} + 2(1-h)\varepsilon/h - f < \underline{p}^{\mathrm{u}} - \varepsilon - \underline{c} - (1-h)(1-q)f/(hq + (1-h)(1-q))$ for ε sufficiently small. Thus, a low-ability expert prefers to recommend a minor treatment even after observing a signal indicating a major problem.

customers believe with a sufficiently high probability that a deviating expert has a low type. Moreover, the type-dependent-treatment equilibria stated in Propositions 4 and 5 can be approached arbitrarily closely with a sufficiently small fine. The worst off-path belief a customer can have is to face a low-ability expert type with probability one; thus, the comparisons are analogous to the comparisons in the proof of Proposition 4.

With a fine bounded away from zero, a low-ability expert type who does not always recommend the major treatment will sometimes pay the fine and hence, make smaller profits than a high-ability expert type. Consequently, with a sufficiently large fine, a low-ability expert type may want to separate from a high-ability expert type, and thus, price pooling may break down.

Proposition 13. *There exists a separating equilibrium (with $\bar{p}_H \neq \bar{p}_L$ and $\underline{p}_H \neq \underline{p}_L$) for all x if and only if either (i) $f \geq (h(1-q)+(1-h)q)\Delta c/h(1-q)$, or (ii) $v-\bar{c} \geq (1-h+hq)v-\bar{c}+(h-2hq+q)\Delta c-h(1-q)f$ and $f \geq (hq+(1-h)(1-q))\Delta c/h(1-q)$, and either $f < (hq+(1-h)(1-q))(v+(1-h)\Delta c)/(1-h)hq$ or $f \geq ((2h-1)(1-q)v/(1-h)+(h(1-q)+(1-h)q)\Delta c)/h(1-q)$, or (iii) $(1-h+hq)v-\bar{c}+(h-2hq+q)\Delta c-h(1-q)f \geq \max\{(1-h)v-\underline{c}-hf, v-\bar{c}\}$, $h < (3-\sqrt{5})/2$, and $f \geq (hv+(1-2h)\Delta c)(hq+(1-h)(1-q))/(1-2h)hq$.*[42]

Clearly, in a separating equilibrium, the high-ability expert manages to earn profits as if his type were observable. The prices the high-ability expert chooses are $\bar{p} = v+(1-h)\Delta c - h(1-q)(1-h)f/(h(1-q)+(1-h)q)$ and $\underline{p} = v+h\Delta c+h^2(1-q)f/(h(1-q)+(1-h)q)$, or $\underline{p} = v-h\Delta c+h^2qf/(hq+(1-h)(1-q))$ and $\bar{p} = v-(1-h)\Delta c-h(1-h)qf/(hq+(1-h)(1-q))$, or $\bar{p}=0$ and $\underline{p} = v/(1-h)$, depending on whether the strongest incentive for separation arises from minimizing $\bar{p}$ or $\underline{p}$, while allowing the high-ability expert to earn first-best profits and ensuring that prices are non-negative. Because choosing the major treatment is the only way to avoid the fine with certainty, this is more attractive for the low-ability expert than the high-ability expert after diagnosing a minor problem. Thus, for a large fine, $\bar{p} < \underline{p}$, to disincentivize the low-ability expert from choosing the major treatment. The low-ability expert always chooses the major treatment in cases (i) and (ii), whereas he follows his diagnosis in case (iii).

Note that if it exists, this equilibrium is also the only equilibrium that does not violate the intuitive criterion. The fine tends to push the low-ability expert to choose the major treatment too often in a separating equilibrium compared to the efficient benchmark. This is because the low-ability expert takes the fine into account, whereas it is just a transfer from a welfare perspective.

Corollary 3. *A fine that induces a separating equilibrium is efficient if and only if (i) $h \geq h_L^{\mathrm{o}}$ or (ii) $(1-h+hq)v-\bar{c}+(h-2hq+q)\Delta c-(1-q)hf \geq \max\{(1-h)v-\underline{c}-hf, v-\bar{c}\}$, $h < (3-\sqrt{5})/2$, $f \geq (hv+(1-2h)\Delta c)(hq+(1-h)(1-q))/q(1-2h)h$, and $h \geq h_L^{\mathrm{u}}$.*

6. 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 sometimes makes mistakes when diagnosing problems.

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 (intentionally). The high-ability expert type 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 diagnosis. 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 because the low-ability expert type could always mimic the high-ability expert type when the high-ability expert type deviates from equal prices. Hence, markups and profits are identical for both expert types, which also implies that there are no private benefits to improving one's diagnostic ability. Increasing transparency through (perfect) certification, that is, making expert types observable, would weakly increase efficiency in our setup.[43] This is especially important in settings in which experts' investments in their diagnostic ability are essential.

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 efficiency does not improve if the probability for a major problem is sufficiently high or sufficiently low. Only for an intermediate likelihood, if the expert types post equal-markup prices and follow their own diagnosis, efficiency increases.

We observe that an infinitesimally costly increase in the share of the high-ability type can even decrease social welfare because the equilibrium outcomes do not change, but costs must be incurred. For example, if expert types coordinate on an equilibrium in which both expert types always provide the major treatment, increasing the probability of 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.

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

[42] The proof can be found in the Appendix.

[43] Note that imperfect certification – often the only feasible option in practice – does not necessarily render our other insights obsolete. There can still be substantial variation in diagnoses, even among highly qualified experts (see, for example, Botvinik-Nezer et al., 2020, Huntington-Klein et al., 2021, Menkveld et al., 2024).

regard, the development of AI-supported tools to support physicians in their diagnostic efforts can be expected to have positive implications.[44]

If the success or failure of a treatment is verifiable, warranties or fines for an insufficient treatment appear to be useful policy tools. Without such verifiability, the optimal policy is not as straightforward.

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

Funding

The authors gratefully acknowledge financial support by the Austrian Science Fund, Austria (SFB F63), the Fritz Thyssen Foundation, Germany, and the German Research Foundation (DFG, project no. 235577387/GRK1974).

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgments

We thank David Levine (Editor), an anonymous Guest Editor, and two anonymous referees for their comments and suggestions, which helped to greatly improve the paper. We are grateful to Felipe A. Araujo, Uwe Dulleck, Winand Emons, Paul Heidhues, Johannes Johnen, Rudolf Kerschbamer, Qianshuo Liu, Anastasia Parakhonyak, Giuseppe Pignataro, Devesh R. Raval, Sigrid Suetens, and audiences at the 17th IIOC (Boston), the NOeG Annual Meeting (Graz), the Midwest Economic Theory and International Trade Conference (Bloomington), the 2019 Asia Meeting of the Econometric Society (Xiamen), the 2019 Econometric Society Australasian Meeting (Perth), the 2019 EARIE (Barcelona), the 2019 JEI (Madrid), the 2019 Annual Meeting of the German Economic Association, the ASSET 2019 Conference (Athens), the Webinar Series on Credence Goods and Expert Markets 2021, and seminars in Innsbruck, Paderborn, Brno (Masaryk University), Frankfurt (Goethe University and Frankfurt School), Mannheim (ZEW), Towson, Washington, D.C. (Howard University and Federal Trade Commission), and Düsseldorf for very helpful comments and discussions. We thank Jennifer Rontganger for proofreading the paper.

Appendix

Proof of Proposition 13. Note that for such a separating equilibrium to exist, the high-ability expert must post a price vector that induces him to make his treatment decision dependent on his diagnosis. Otherwise, the low-ability type could imitate him and earn the same profits. Let us now analyze the different cases that can arise, depending on which price vector would be optimal for the low-ability expert under separation. In each case, we determine the price vector that minimizes the low-ability expert's profits from price pooling, while still incentivizing the high-ability expert to follow his signal and earning him first-best profits. A high-ability expert could choose such a price vector to deter a low-ability expert from price pooling, without reducing his own profits. In general, a high-ability expert might be willing to lower both prices to discourage price pooling, if his profits from separation – albeit at slightly below first-best prices – exceed his profits from pooling. We focus on the limit where the share of high-ability experts approaches one. In that case, price pooling yields the high-ability expert his maximum profits, so reducing prices to separate would never be optimal. Thus, the conditions we derive are sufficient and also necessary as $x \to 1$.

First, assume that posting a price vector that induces the low-ability expert to choose the major treatment is profit-maximizing in the case of separation. This can be ensured by assuming that v is sufficiently large, that is, $v - \bar{c} \geq (1-h+hq)v - \bar{c} + (h-2hq+q)\Delta c - h(1-q)f$. Then, assume that (i) price pooling induces the low-ability expert to always choose the major treatment, while it induces the high-ability expert to follow his diagnosis: $\underline{p} - \underline{c} \geq \bar{p} - \bar{c} \geq \underline{p} - \underline{c} - h(1-q)f/(h(1-q)+(1-h)q)$, where $\bar{p}$ is chosen as small as possible to minimize the low-ability expert's profits and $h\bar{p} + (1-h)\underline{p} = v$ (the expected price extracting the customer's willingness to pay). Thus, $\bar{p} = v + (1-h)\Delta c - h(1-q)(1-h)f/(h(1-q)+(1-h)q)$ and $\underline{p} = v + h\Delta c + h^2(1-q)f/(h(1-q)+(1-h)q)$, assuming that $\bar{p} \geq 0$. Then, separation is optimal for all x if and only if $v - \bar{c} \geq v - \bar{c} + (1-h)\Delta c - h(1-q)(1-h)f/(h(1-q)+(1-h)q) \Leftrightarrow f \geq (h(1-q)+(1-h)q)\Delta c/h(1-q)$. Note that this implies $v - \bar{c} \geq (1-h+hq)v - \bar{c} + (h-2hq+q)\Delta c - h(1-q)f$. Next, assume that (ii) under price pooling, the low-ability expert always chooses the minor treatment, while the high-ability expert continues to follow his diagnosis: $\underline{p} - \underline{c} - hqf/(hq+(1-h)(1-q)) \geq \bar{p} - \bar{c} \geq \underline{p} - \underline{c} - f$, where $\underline{p}$ is chosen as small as possible to minimize the low-ability expert's profits and $h\bar{p} + (1-h)\underline{p} = v$ (the expected price extracting the customer's willingness to pay). Thus, $\underline{p} = v - h\Delta c + h^2qf/(hq+(1-h)(1-q))$ and $\bar{p} = v - (1-h)\Delta c - h(1-h)qf/(hq+(1-h)(1-q))$, assuming that $\bar{p} \geq 0$. Then, separation is optimal for all x if and only if

[44] See, for example, https://www.cimd.fraunhofer.de/en/projects/artificial- intelligence-for-diagnostic-support.html (accessed on July 5, 2023).

$v-\bar{c} \geq v-h\Delta c+h^2qf/(hq+(1-h)(1-q))-\underline{c}-hf \Leftrightarrow f \geq (hq+(1-h)(1-q))\Delta c/h(1-q)$. Finally, assume that (iii) price pooling induces both expert types to follow their signal: $\underline{p}-\underline{c}-h(1-q)f/(h(1-q)+(1-h)q) \geq \bar{p}-\bar{c} \geq \underline{p}-\underline{c}-hqf/(hq+(1-h)(1-q))$. Choosing either $\bar{p}$ or $\underline{p}$ as small as possible (and the other as large as possible) maximizes the incentives for separation. This results in the same prices and profits – and therefore the same incentives for separation – as in cases (i) or (ii). Consequently, under the assumption that always choosing the major treatment in the separating case is optimal for the agent, a separating equilibrium exists for all x if and only if $f \geq \min\{(h(1-q)+(1-h)q)\Delta c/h(1-q), (hq+(1-h)(1-q))\Delta c/h(1-q)\}$. If $\bar{p} \geq 0$ becomes binding, let $\bar{p}=0$ and $\underline{p}=v/(1-h)$. If $f > (h(1-q)+(1-h)q)(v+(1-h)\Delta c)/h(1-h)(1-q)$ (note that this implies $f \geq (h(1-q)+(1-h)q)\Delta c/h(1-q)$), then always choosing the major treatment is optimal for the low-ability expert under price pooling. Clearly, profits would be negative in this case, so separation is optimal for the low-ability expert. If $(h(1-q)+(1-h)q)(v+(1-h)\Delta c)/h(1-h)(1-q) > f \geq (hq+(1-h)(1-q))(v+(1-h)\Delta c)/hq(1-h)$, then always following his diagnosis is optimal for the low-ability expert under price pooling. Separation is optimal if $v-\bar{c} \geq -\bar{c}(hq+(1-h)(1-q))+(v/(1-h)-\underline{c})(h(1-q)+(1-h)q)-h(1-q)f \Leftrightarrow f \geq ((2h-1)(1-q)v/(1-h)+(h(1-q)+(1-h)q)\Delta c)/h(1-q)$.

Second, assume that posting a price vector that induces the low-ability expert to choose the minor treatment is profit-maximizing in the case of separation. That is, $(1-h)v-\underline{c}-hf \geq (1-h+hq)v-\bar{c}+(h-2hq+q)\Delta c-h(1-q)f$. Note that the non-negativity constraint for $\bar{p}$ is never binding in this case. Now, assume that (i) price pooling induces the low-ability expert to always choose the major treatment, while inducing the high-ability expert to follow his diagnosis. The prices are the same as above. The low-ability expert's profits from separation are larger than from pooling if and only if $(1-h)v-\underline{c}-hf \geq v-\bar{c}+(1-h)\Delta c-h(1-q)(1-h)f/(h(1-q)+(1-h)q) \Leftrightarrow (h(1-q)+(1-h)q)\Delta c-v \geq (h(1-q)+(1-h)q-(1-h)(1-q))f$. This inequality is never satisfied for non-negative f, as the left-hand side is negative while the right-hand side is non-negative. Next, assume that (ii) price pooling induces the low-ability expert to always choose the minor treatment, while again inducing the high-ability expert to follow his diagnosis. The low-ability expert's profits from separation are larger than from pooling if $(1-h)v-\underline{c}-hf \geq v-h\Delta c+h^2qf/(hq+(1-h)(1-q))-\underline{c}-hf \Leftrightarrow (hq+(1-h)(1-q))(\Delta c-v)/hq \geq f$. Again, this inequality is never satisfied for non-negative f, as the left-hand side is negative and the right-hand side is non-negative. Finally, assume that (iii) price pooling induces both expert types to follow their signal. Again, the prices and profits are the same as in either (i) or (ii), which implies the same incentives for separation. Consequently, under the assumption that always choosing the minor treatment in the case of separation is optimal for the agent, no separating equilibrium exists for any x.

Third, assume that posting a price vector that induces the low-ability expert to follow his diagnosis is profit-maximizing in the case of separation. That is, $(1-h+hq)v-\bar{c}+(h-2hq+q)\Delta c-(1-q)hf \geq \max\{(1-h)v-\underline{c}-hf, v-\bar{c}\}$. Assume for now that the non-negativity constraint for $\bar{p}$ does not bind. Then, assume that (i) price pooling induces the low-ability expert to always choose the major treatment (while inducing the high-ability expert to follow his diagnosis). The prices are the same as above. The low-ability expert's profits from separation are larger than from pooling if and only if $(1-h+hq)v-\bar{c}+(h-2hq+q)\Delta c-h(1-q)f \geq v-\bar{c}+(1-h)\Delta c-h(1-h)(1-q)f/(h(1-q)+(1-h)q) \Leftrightarrow f \geq (hv+(1-2h)\Delta c)(h(1-q)+(1-h)q)/h(1-2h)(1-q)$, if $h \leq 1/2$. Otherwise, this inequality never holds. Next, assume that (ii) price pooling induces the low-ability expert to always choose the minor treatment (while again inducing the high-ability expert to follow his diagnosis). The low-ability expert's profits from separation are larger than from pooling if $(1-h+hq)v-\bar{c}+(h-2hq+q)\Delta c-h(1-q)f \geq v-h\Delta c+h^2qf/(hq+(1-h)(1-q))-\underline{c}-hf \Leftrightarrow f \geq (hv+(1-2h)\Delta c)(hq+(1-h)(1-q))/h(1-2h)q$, if $h < 1/2$. Otherwise, this inequality never holds. Finally, assume that (iii) price pooling induces both expert types to follow their signal. Again, the prices and profits are the same as in either (i) or (ii), which implies the same incentives for separation. Consequently, under the assumption that always following his signal in the case of separation is optimal for the agent, no separating equilibrium exists for any x if $h \geq 1/2$. Because the threshold of (ii) is smaller than that of (i) (as $q > 1/2$), the threshold of (ii) is the relevant one for $h < 1/2$. So if $h < 1/2$, a separating equilibrium exists for all x if and only if $f \geq (hv+(1-2h)\Delta c)(hq+(1-h)(1-q))/h(1-2h)q$. The non-negativity constraint for $\bar{p}$ does not bind in case (i); otherwise, we would be in the first case. Let us now discuss when $\bar{p} \geq 0$ becomes binding in cases (ii) or (iii), that is, $(h(1-q)+(1-h)q)(v+(1-h)\Delta c)/h(1-h)(1-q) > f \geq (hq+(1-h)(1-q))(v+(1-h)\Delta c)/h(1-h)q$. Then, always following his diagnosis is optimal for the low-ability expert under price pooling, with $\bar{p}=0$ and $\underline{p}=v/(1-h)$. Separation is optimal if $(1-h+hq)v-\bar{c}+(h-2hq+q)\Delta c-h(1-q)f \geq -\bar{c}(hq+(1-q)(1-h))+(v/(1-h)-\underline{c})(h(1-q)+(1-h)q)-h(1-q)f \Leftrightarrow h \leq (3-\sqrt{5})/2$. Because for $(3-\sqrt{5})/2 \leq h \leq 1/2$, the condition $f \geq (hv+(1-2h)\Delta c)(hq+(1-h)(1-q))/h(1-2h)q$ implies $f \geq (hq+(1-h)(1-q))(v+(1-h)\Delta c)/h(1-h)q$, the non-negativity constraint $\bar{p} \geq 0$ binds in this case, which means that there is no separating equilibrium. For $h \leq (3-\sqrt{5})/2$, the implication is reversed: $f \geq (hq+(1-h)(1-q))(v+(1-h)\Delta c)/h(1-h)q \Rightarrow f \geq (hv+(1-2h)\Delta c)(hq+(1-h)(1-q))/h(1-2h)q$, so the threshold in (ii) is the relevant one: $f \geq (hv+(1-2h)\Delta c)(hq+(1-h)(1-q))/h(1-2h)q$. □

Data availability

No data was used for the research described in the article.

References

Adrion, E.R., Ryan, A.M., Seltzer, A.C., Chen, L.M., Ayanian, J.Z., Nallamothu, B.K., 2016. Out-of-pocket spending for hospitalizations among nonelderly adults. JAMA Intern. Med. 176, 1325–1332.

Alger, I., Salanié, F., 2006. A theory of fraud and overtreatment in experts markets. J. Econ. Manag. Strat. 15, 853–881.

Ayouni, M., Lanzi, T., 2023. Redence goods, consumer feedback, and (in)efficiency. Work. Pap..

Balafoutas, L., Beck, A., Kerschbamer, R., Sutter, M., 2013. What drives taxi drivers? A field experiment on fraud in a market for credence goods. Rev. Econ. Stud. 80, 876–891.

Balafoutas, L., Fornwagner, H., Kerschbamer, R., Sutter, M., Tverdostup, M., 2023. Diagnostic uncertainty and insurance in credence goods markets. ECONtribute Discuss. Pap. No. 257.

Balafoutas, L., Kerschbamer, R., Sutter, M., 2017. Second-degree moral hazard in a real-world credence goods market. Econ. J. 127, 1–18.
Baumann, F., Rasch, A., 2024. Second opinions and diagnostic uncertainty in expert markets. J. Inst. Theor. Econ. 180 (1), 74–105.
Bester, H., Dahm, M., 2018. Credence goods, costly diagnosis and subjective evaluation. Econ. J. 128, 1367–1394.
Bindra, P.C., Kerschbamer, R., Neururer, D., Sutter, M., 2021. On the value of second opinions: A credence goods field experiment. Econom. Lett. 205, 109925.
Botvinik-Nezer, R., Holzmeister, F., Camerer, C.F., Dreber, A., Huber, J., Johannesson, M., Kirchler, M., Iwanir, R., Mumford, J.A., Adcock, R.A., et al., 2020. Variability in the analysis of a single neuroimaging dataset by many teams. Nature 582, 84–88.
Brammer, R., 2002. Effects of experience and training on diagnostic accuracy. Psychol. Assess. 14, 110–113.
Brush, J.E., Sherbino, J., Norman, G.R., 2017. How expert clinicians intuitively recognize a medical diagnosis. Am. J. Med. 130, 629–634.
Chan, D.C., Gentzkow, M., Yu, C., 2022. Selection with variation in diagnostic skill: Evidence from radiologists. Q. J. Econ. 137 (2), 729–783.
Chen, Y., Li, J., Zhang, J., 2022. Efficient liability in expert marktes. Internat. Econom. Rev. 63 (4), 1717–1744.
Coderre, S., Jenkins, D., McLaughlin, K., 2009. Qualitative differences in knowledge structure are associated with diagnostic performance in medical students. Adv. Heal. Sci. Educ. 14, 677–684.
Crettez, B., Deloche, R., Jeanneret-Crettez, M.-H., 2020. A demand-induced overtreatment model with heterogeneous experts. J. Public Econ. Theory 22, 1713–1733.
Dai, T., Singh, S., 2020. Conspicuous by its absence: Diagnostic expert testing under uncertainty. Mark. Sci. 39 (3), 540–563.
Dai, T., Singh, S., 2024. Artificial intelligence on call: The physician's decision of whether to use AI in clinical practice. Johns Hopkins Carey Bus. Sch. Res. Pap. No. 22-02.
Darby, M.R., Karni, E., 1973. Free competition and the optimal amount of fraud. J. Law Econ. 16, 67–88.
Dulleck, U., Kerschbamer, R., 2006. On doctors, mechanics, and computer specialists: The economics of credence goods. J. Econ. Lit. 44, 5–42.
Dulleck, U., Kerschbamer, R., 2009. Experts vs. discounters: Consumer free-riding and experts withholding advice in markets for credence goods. Int. J. Ind. Organ. 27, 15–23.
Dulleck, U., Kerschbamer, R., Sutter, M., 2011. The economics of credence goods: An experiment on the role of lability, verifiability, reputation, and competition. Am. Econ. Rev. 101, 526–555.
ECDC Technical Report, 2019. Survey of healthcare workers' knowledge, attitudes and behaviours on antibiotics, antibiotic use and antibiotic resistance in the EU/EEA.
Ely, J., Fudenberg, D., Levine, D.K., 2008. When is reputation bad? Games Econom. Behav. 63 (2), 498–526.
Ely, J.C., Välimäki, J., 2003. Bad reputation. Q. J. Econ. 118 (3), 785–814.
Emons, W., 1997. Credence goods and fraudulent experts. RAND J. Econ. 28, 107–119.
Emons, W., 2001. Credence goods monopolists. Int. J. Ind. Organ. 19, 375–389.
Federal Bureau of Investigation, 2011. Financial crimes report to the public: Fiscal year 2010–2011. United States Department of Justice.
Fong, Y.-f., 2005. When do experts cheat and whom do they target? RAND J. Econ. 36, 113–130.
Fong, Y.-f., Liu, T., Wright, D.J., 2014. On the role of verifiability and commitment in credence goods markets. Int. J. Ind. Organ. 37, 118–129.
Fong, Y.-f., Meng, X., Zhao, L., 2022. Laboratory kickback to doctor, consumer awareness, and welfare implications. Work. Pap..
Frankel, A., Schwarz, M., 2014. Experts and their records. Econ. Inq. 52, 56–71.
Gottschalk, F., Mimra, W., Waibel, C., 2020. Health services as credence goods: A field experiment. Econ. J. 130 (629), 1346–1383.
Hall, J., Kerschbamer, R., Neururer, D., Skoog, E., 2025. Uncovering sophisticated discrimination with the help of credence goods markups: Evidence from a natural field experiment. Manag. Sci. 71 (1), 694–707.
Heinzel, J., 2019a. Credence goods markets with fair and opportunistic experts. Work. Pap. Cent. Int. Econ. No. 2019-02.
Heinzel, J., 2019b. Credence goods markets with heterogeneous experts. Work. Pap. Cent. Int. Econ. No. 2019-01.
Hilger, N.G., 2016. Why don't people trust experts? J. Law Econ. 59, 293–311.
Huntington-Klein, N., Arenas, A., Beam, E., Bertoni, M., Bloem, J.R., Burli, P., Chen, N., Grieco, P., Ekpe, G., Pugatch, T., Saavedra, M., Stopnitzky, Y., 2021. The influence of hidden researcher decisions in applied microeconomics. Econ. Inq. 59 (3), 944–960.
Hyndman, K., Ozerturk, S., 2011. Consumer information in a market for expert services. J. Econ. Behav. Organ. 80, 628–640.
Inderst, R., 2015. Regulating commissions in markets with advice. Int. J. Ind. Organ. 43, 137–141.
Inderst, R., Ottaviani, M., 2012a. Competition through commissions and kickbacks. Am. Econ. Rev. 102, 780–809.
Inderst, R., Ottaviani, M., 2012b. Financial advice. J. Econ. Lit. 50, 494–512.
Inderst, R., Ottaviani, M., 2012c. How (not) to pay for advice: A framework for consumer financial protection. J. Financ. Econ. 105, 393–411.
Jiang, B., Ni, J., Srinivasan, K., 2014. Signaling through pricing by service providers with social preferences. Mark. Sci. 33 (5), 641–654.
Jost, P.-J., Reik, S., Ressi, A., 2021. The information paradox in a monopolist's credence goods market. Int. J. Ind. Organ. 75, 102694.
Kerschbamer, R., Neururer, D., Sutter, M., 2016. Insurance coverage of customers induces dishonesty of sellers in markets for credence goods. Proc. Natl. Acad. Sci. 113, 7454–7458.
Kerschbamer, R., Neururer, D., Sutter, M., 2023. Credence goods markets, online information and repair prices: A natural field experiment. J. Public Econ. 222, 104891.
Kerschbamer, R., Sutter, M., 2017. The economics of credence goods—A survey of recent lab and field experiments. CESifo Econ. Stud. 63, 1–23.
Kerschbamer, R., Sutter, M., Dulleck, U., 2017. How social preferences shape incentives in (experimental) markets for credence goods. Econ. J. 127, 393–416.
Kondori, I., Mottin, R.W., Laskin, D.M., 2011. Accuracy of dentists in the clinical diagnosis of oral lesions. Quintessence Int. 42 (7), 575–577.
Lambert, L.E., Wertheimer, M., 1988. Is diagnostic ability related to relevant training and experience? Prof. Psychol.: Res. Pr. 19, 50–52.
Li, X., Lu, J., Hu, S., Cheng, K., De Maeseneer, J., Meng, Q., Mossialos, E., Xu, D.R., Yip, W., Zhang, H., Krumholz, H.M., Jiang, L., Hu, S., 2017. The primary health-care system in China. Lancet 390, 2584–2594.
Liu, T., 2011. Credence goods markets with conscientious and selfish experts. Internat. Econom. Rev. 52, 227–244.
Liu, T., Ma, C.-t.A., 2024. Equilibrium information in credence goods. Games Econom. Behav. 145, 84–101.
McGuire, T.G., 2000. Physician agency. In: Culyer, A.J., Newhouse, J.P. (Eds.), Handbook of Health Economics. vol. 1, Part A, Elsevier, pp. 461–536.
Menkveld, A.J., Dreber, A., Holzmeister, F., Huber, J., Johannesson, M., Kirchler, M., Neusüss, S., Razen, M., Weitzel, U., et al., 2024. Non-standard errors. J. Financ. 79 (3), 2339–2390.
Mimra, W., Rasch, A., Waibel, C., 2016a. Price competition and reputation in credence goods markets: Experimental evidence. Games Econom. Behav. 100, 337–352.
Mimra, W., Rasch, A., Waibel, C., 2016b. Second opinions in markets for expert services: Experimental evidence. J. Econ. Behav. Organ. 131, 106–125.
Momsen, K., 2021. Recommendations in credence goods markets with horizontal product differentiation. J. Econ. Behav. Organ. 183, 19–38.
Mullainathan, S., Obermeyer, Z., 2021. Diagnosing physician error: A machine learning approach to low-value health care. Q. J. Econ. 137 (2), 679–727.
Obradovits, M., Plaickner, P., 2024. Searching for treatment. J. Inst. Theor. Econ. 180 (1), 144–186.
OECD, 2019. Out-of-pocket spending: Access to care and financial protection.
Pesendorfer, W., Wolinsky, A., 2003. Second opinions and price competition: Inefficiency in the market for expert advice. Rev. Econ. Stud. 70, 417–437.
Pham, H.H., Alexander, G.C., O'Malley, A.S., 2007. Physician consideration of patients' out-of-pocket costs in making common clinical decisions. Arch. Intern. Med. 167, 663–668.
Rasch, A., Waibel, C., 2018. What drives fraud in a credence goods market? Evidence from a field study. Oxf. Bull. Econ. Stat. 80, 605–624.

Schneider, H.S., 2012. Agency problems and reputation in expert services: Evidence from auto repair. J. Ind. Econ. 60, 406–433.

Schneider, T., Bizer, K., 2017a. Effects of qualification in expert markets with price competition and endogenous verifiability. Work. Pap. Cent. Eur. Gov. Econ. Dev. Res. No. 317.

Schneider, T., Bizer, K., 2017b. Expert qualification in markets for expert services: A sisyphean task? Discuss. Pap. Cent. Eur. Gov. Econ. Dev. Res. No. 323.

Schniter, E., Tracy, J.D., Zíka, V., 2021. Uncertainty and reputation effects in credence goods markets. Work. Pap..

Szech, N., 2011. Becoming a bad doctor. J. Econ. Behav. Organ. 80, 244–257.

Taylor, C.R., 1995. The economics of breakdowns, checkups, and cures. J. Political Econ. 103, 53–74.

Xue, H., Shi, Y., Huang, L., Yi, H., Zhou, H., Zhou, C., Kotb, S., Tucker, J.D., Sylvia, S.Y., 2019. Diagnostic ability and inappropriate antibiotic prescriptions: A quasi-experimental study of primary care providers in rural China. J. Antimicrob. Chemother. 74, 256–263.