Documents de travail

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Document de Travail n° 2022 – 27

Septembre 2022

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Credence goods, consumer feedback and (in)efficiency*†

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September 2022

Abstract

We analyze the effects of consumer feedback on a credence goods market. We present a model inspired by Dulleck and Kerschbamer (2006) where consumers sequentially visit a monopolistic expert. Each consumer faces a problem which can be either minor or major. The expert performs a diagnosis that may or may not reveal the severity of the problem faced by each consumer. He then implements a treatment which can solve the problem or not. After visiting the expert, each consumer reveals the received treatment and its outcome, i.e., whether it solved her problem. Each consumer receives the feedback from all previous consumers and uses it to update her belief about the informativeness of the expert's diagnosis. She then decides whether to visit the expert. We show that consumer feedback can lead to inefficiency. More precisely, when the diagnosis fails, the expert overtreats consumers whereas the probability of a major problem is sufficiently low. This behavior does not arise without consumer feedback.

Keywords: Consumer feedback; Credence goods; Expert; Overtreatment; Reputation.
JEL Codes: D82, D83.

*The authors gratefully acknowledge financial support provided by ANR via the grant NICETWEET, number ANR-20-CE48-000 and by the French Ministry of Justice via Mission de Recherche Droit et Justice.

†For helpful comments and suggestions, we thank Tim Friehe, Frédéric Koessler and the participants of the ANR NICETWEET Meeting (Avignon, October 2021), Séminaire Cournot (Strasbourg, January 2022), Séminaire LIEN (Nanterre, March 2022) and the 19th annual conference of the German Law and Economics Association (Nancy, July 2022).

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1 Introduction

1.1 Overview of the problem

It is largely understood today that the success of online marketplaces is not only due to the immediate access to a wide range of goods and services, but also to a major innovation first introduced by eBay: online feedback mechanisms[1] (Tadelis (2016), Dellarocas (2003)). Consumer feedback is one such mechanism that allows the transmission of a collection of information provided by consumers about their experience with goods and services. Consumer feedback on online marketplaces is analogous to word-of-mouth and this mechanism has become crucial in guiding individual purchase decisions thanks to the development of the Internet[2].

Whereas it is quite common for consumers to consult reviews for experience goods or search goods on online marketplaces such as Amazon or Google shopping before making a purchase, we observe that there is an increasing number of platforms for credence goods where consumer feedback plays a similar role[3]. For instance, the development of legal technology favors the rise of legal platforms such as *avvo.com* or *lawyers.com* where potential clients can find information concerning lawyers and their services (education, areas of expertise, pricing policy, ...) and reviews from previous clients. On credence goods markets, consumer feedback may pertain to their perception of the expert, his methodology, the implemented treatment and its outcome. Such dedicated platforms also exist for other credence goods markets such as repair services or medical care[4].

Markets for credence goods (or markets for expert services) are markets in which experts are better informed than consumers about their needs both *ex ante* and *ex post*. Indeed, it is true *ex ante* because an expert is better equipped to assess (not necessary perfectly) the type or quality of the good or service the consumer needs than the consumer herself. But it is also true *ex post* because the consumer will be unable to determine whether the type or quality of the good or service that she has received and paid for was the appropriate one. As many markets characterized by asymmetric information, credence goods markets may generate inefficiencies which are caused by the strategic behavior of fraudulent experts. Information given by consumer feedback may contribute to reduce asymmetric information and have significant impacts on efficiency on credence goods markets. In this paper, we investigate the way consumer feedback affects the efficiency on a credence goods markets. In particular, we consider a credence goods market with a finite number of consumers and a monopolistic expert and we analyze the effects of consumer

[1] Resnick et al. (2000) talk about *reputation systems*.

[2] The empirical literature is unanimous concerning the fact that online reviews have significant effects on consumers' purchasing behavior (see for instance Cabral (2012) for a presentation of these effects.). Moreover, according to a BrightLocal survey (https://www.brightlocal.com/research/local-consumer-review-survey/), 85% of consumers interrogated are influenced by the overall average star rating of a seller before a purchasing decision.

[3] Kerschbamer et al. (2019) identify internet reviews as a crucial channel "which can help to identify expert sellers who provide appropriate quality at reasonable prices".

[4] More generally, websites such as Google or Yelp give access to several types of credence goods providers and allow consumers to give feedback and rate sellers.

feedback on the strategic behavior of consumers and the expert. In this setting, we show that consumer feedback can be a new source of inefficiencies and, in particular, a source of overtreatment[5].

We investigate this question by introducing consumer feedback in the framework of Dulleck and Kerschbamer (2006) (henceforth DK06). DK06 developed a tractable model of credence goods where each consumer faces a problem which can be either major or minor. Expert(s) are able to recommend and provide a treatment after making a diagnosis. There exists an expensive treatment for the major problem and a cheap one for the minor problem. A consumer who decides to visit an expert has to pay a price for the provided treatment. DK06 consider four assumptions, namely homogeneity (H), commitment (C), liability (L) and verifiability (V), and study several settings with different combinations of these assumptions. Assumption H states that the likelihood of having a major problem and the valuation of treatment outcomes do not differ from one consumer to another. Assumption C states that a consumer who visits an expert has to accept the recommended treatment. Assumption L states that an expert cannot provide the cheap treatment when the expensive one is needed. Finally, assumption V states that an expert cannot provide the cheap treatment and charge for the expensive one.

Based on this model, DK06 identify two basic problems on markets for credence goods. First, it is possible that the treatment provided by an expert does not fit the consumer's needs. This refers to either undertreatment or overtreatment depending on the matching between the treatment and the needs. Second, it is possible that the expert overcharges the consumer by asking for the price of the expensive treatment while providing the cheap one. Using different combinations of these four assumptions, DK06 managed to reproduce most existing results on inefficiencies and fraud on credence goods markets and determined combinations under which the price mechanism is sufficient to solve the fraudulent expert problem.

Their model is also based on the assumption that the diagnosis performed by the expert is fully informative so that he always perfectly determines consumers' needs. In such a case, assumption L solves trivially the undertreatment problem. In our model, we introduce the notion of *diagnosis informativeness* and allow for the possibility of diagnosis failure so that the expert may obtain no additional information concerning consumers' needs. In such a case, it is possible that the expert provides by mistake an insufficient treatment. Thus, his liability is mitigated by the possibility of diagnosis failure and we drop assumption L. Consequently, we restrict attention to the combination H, C and V which leads to efficiency in DK06. In this setting, we consider a situation where after

[5]As we discuss below, overtreatment is a well-known problem on credence goods markets. For instance, overtreatment appears in health care markets when a physician chooses a quantity of treatment higher than the one that would be chosen by a fully informed patient. This refers to the famous problem of physician-induced demand in health economics (Rice (1983)). Using a field experiment concerning the market for auto repairs, Schneider (2012) estimates that about 30% of mechanics recommend unnecessary repairs. He notably observes that a common overtreatment for the intermittent starting problem is to replace a healthy starter motor instead of tightening the loose battery cable. Legal services are not spared by overtreatment. Willis (2021) collects testimonials from lawyers who admit to overbilling from time to time, not by claiming undone work, but by performing unnecessary tasks.

visiting the expert, each consumer gives feedback about the treatment implemented by the expert and its outcome, i.e., whether her problem was fixed or not. We consider a feedback mechanism where each consumer has access to feedback from all previous consumers and uses it to update her belief about the informativeness of the expert's diagnosis. She then decides whether to visit the expert. The expert has to take into account the effect of each feedback on consumers' beliefs and decisions when he chooses his prices and treatment strategy.

In such a setting, the main result of our paper is that consumer feedback may lead to inefficiency. More precisely, when the diagnosis fails, the expert overtreats consumers whereas the probability of a major problem is sufficiently low. This behavior does not arise without consumer feedback. Overtreatment allows the expert to manage his reputation since the expensive treatment guarantees that the problem faced by each consumer will be solved independently of its severity. This avoids the risk of treatment failure which occurs when the cheap treatment is provided while the problem is major and which may lead future consumers to decide not to visit the expert. Moreover, overtreatment allows the expert to implement higher prices which guarantees him a greater payoff. The following example highlights the intuition behind the main result of the paper and presents the way we model consumer feedback.

1.2 Motivation and intuition

In this section, we provide an example in order to motivate and give some intuition about our main result that consumer feedback can lead to inefficiency. The example is based on a modified version of DK06 which allows us to illustrate our result in a simpler setting than the general model.

We consider a market with a monopolistic expert (E) and two consumers denoted by C_1 and C_2. Consumer C_k faces a problem of severity θ_k which is major ($\theta_k = \overline{\theta}$) with probability $h = 2/5$ and minor ($\theta_k = \underline{\theta}$) with probability $1 - h = 3/5$. We assume that θ_1 and θ_2 are independent. Consumer C_k can visit the expert in order to get one of two treatments denoted $\underline{t}$ and $\bar{t}$. We denote by $c(t)$ the *social cost* of treatment t such that $c(\underline{t}) = 0$ ($\underline{t}$ is the cheap treatment) and $c(\bar{t}) = 1/2$ ($\bar{t}$ is the expensive treatment). Before consumers visit the expert, Nature determines whether his diagnosis is going to be informative (i.e., reveals the severity of consumers' problems) or not (i.e., reveals no additional information). The diagnosis is informative with probability $\lambda = 1/2$[6].

We assume that the expert's objective is to maximize the expected number of consumer visits[7]. If consumer C_k visits the expert and gets treatment t_k, the *gross social surplus* $u(\theta_k, t_k)$ that is generated depends on the severity of her problem and the treatment chosen by the expert:

[6]In DK06 the diagnosis is perfectly informative, i.e., $\lambda = 1$.

[7]This assumption eliminates the strategic choice of prices which, as in DK06, we consider in the general setting.

$$u(\theta_k, t_k) = \begin{cases} 0 & \text{if } \theta_k = \overline{\theta} \text{ and } t_k = \underline{t} \\ 1 & \text{otherwise} \end{cases}$$

This utility function expresses the fact that the expensive treatment $\overline{t}$ always solves the problem of consumer C_k whatever its severity whereas the cheap treatment $\underline{t}$ only solves the minor problem $\underline{\theta}$.

The *net social surplus* from consumer C_k's visit is $W(\theta_k, t_k) = u(\theta_k, t_k) - c(t_k)$. If the diagnosis is informative, the efficient treatment (i.e., the treatment that maximizes $W(\theta_k, t_k)$) is

$$t^e(\theta_k) = \begin{cases} \underline{t} & \text{if } \theta_k = \underline{\theta} \\ \overline{t} & \text{if } \theta_k = \overline{\theta} \end{cases}$$

If the diagnosis is uninformative, the efficient treatment is the treatment that maximizes the expected net social surplus

$$\mathbb{E}(W(\theta_k, t_k)) = (hu(\overline{\theta}, t_k) + (1 - h)u(\underline{\theta}, t_k)) - c(t_k)$$

With the parameter values defined above, we have $\mathbb{E}(W(\theta_k, \underline{t})) = 3/5$ and $\mathbb{E}(W(\theta_k, \overline{t})) = 1/2$. Therefore, if the diagnosis is uninformative, the efficient treatment is $\underline{t}$.

Assume that the expert chooses the efficient treatment if he is indifferent between $\underline{t}$ and $\overline{t}$ and that each consumer visits the expert if and only if she believes that the diagnosis is informative with a probability that is higher than the threshold $\hat{\mu}$ with $\hat{\mu} > 0$[8].

In the absence of feedback, both consumers believe that the diagnosis is informative with probability 1/2 (i.e., the prior probability λ). Thus, both consumers visit the expert if $\hat{\mu} < 1/2$. Otherwise, both choose not to visit the expert. In the remainder, assume $\hat{\mu} < 1/2$. Under this assumption, both consumers visit the expert. Consequently, the expert is indifferent between treatments $\underline{t}$ and $\overline{t}$ and chooses the efficient one for each consumer.

We now introduce consumer feedback: after visiting the expert[9], consumer C_1 reveals to consumer C_2 the treatment t_1 she received and the value of $u_1 = u(\theta_1, t_1)$ (note that neither consumer observes θ_1 directly). Consumer C_2 updates her belief about diagnosis informativeness before deciding whether to visit the expert or not. The set of possible values of feedback (t_1, u_1) is $\{(\overline{t}, 1), (\underline{t}, 1), (\underline{t}, 0)\}$. It is impossible to have $(\overline{t}, 0)$ because treatment $\overline{t}$ fixes both minor and major problems.

Assume that the expert implements the efficient treatment if the diagnosis is informative. This implies that the expert behaves strategically only when his diagnosis is uninformative[10]. Due to Bayes' rule, consumer C_2's belief is given by μ, the probability

[8]In the general setting, each consumer decides whether to visit the expert based on the comparison between the expected utility of treatment and its expected price.

[9]Consumer C_1 gets no additional information and visits the expert because her belief is equal to the prior and $\hat{\mu} < 1/2$.

[10]We also make this assumption in the general setting. See Section 4 for further details.

that the diagnosis is informative conditional on the observed feedback (t_1, u_1), which is

$$\mu = \frac{\lambda \mathbb{P}((t_1, u_1) \mid \text{ID})}{\lambda \mathbb{P}((t_1, u_1) \mid \text{ID}) + (1-\lambda)\mathbb{P}((t_1, u_1) \mid \text{UD})}$$

where ID stands for "Informative Diagnosis" and UD stands for "Uninformative Diagnosis". It follows that

$$\mu = \begin{cases} \frac{\lambda h}{\lambda h + (1-\lambda)\alpha} = \frac{2}{2+5\alpha} & \text{if } (t_1, u_1) = (\bar{t}, 1) \\ \\ \frac{\lambda(1-h)}{\lambda(1-h)+(1-\lambda)(1-h)(1-\alpha)} = \frac{1}{2-\alpha} & \text{if } (t_1, u_1) = (\underline{t}, 1) \\ \\ 0 & \text{if } (t_1, u_1) = (\underline{t}, 0) \end{cases} \tag{1}$$

where α describes consumer C_2's expectation about the expert's treatment decision with consumer C_1 under uninformative diagnosis: $\alpha = 0$ if she thinks it is treatment $\underline{t}$ and $\alpha = 1$ if she thinks it is treatment $\bar{t}$. Equation 1 is obtained using the following observations:

1. $\mathbb{P}((t_1, u_1) = (\bar{t}, 1) \mid \text{ID}) = h$: under informative diagnosis, the expert chooses the efficient treatment by assumption which implies that consumer C_1's feedback is $(\bar{t}, 1)$ if and only if $\theta_1 = \overline{\theta}$ and this occurs with probability h.

2. Similarly, $\mathbb{P}((t_1, u_1) = (\underline{t}, 1) \mid \text{ID}) = 1-h$: under informative diagnosis, C_1's feedback is $(\underline{t}, 1)$ if and only if $\theta_1 = \underline{\theta}$ and this occurs with probability $1-h$.

3. $\mathbb{P}((t_1, u_1) = (\bar{t}, 1) \mid \text{UD}) = \alpha$: under uninformative diagnosis, C_1's feedback is $(\bar{t}, 1)$ if and only if the expert chooses treatment $\bar{t}$. This is due to the fact that $u_1(\theta_1, \bar{t}) = 1$ regardless of θ_1. Thus, this probability is equal to α.

4. $\mathbb{P}((t_1, u_1) = (\underline{t}, 1) \mid \text{UD}) = (1-h)(1-\alpha)$: under uninformative diagnosis, C_1's feedback is $(\underline{t}, 1)$ if and only if the expert chooses treatment $\underline{t}$ and $\theta_1 = \underline{\theta}$. Thus, this probability is equal to $(1-h)(1-\alpha)$.

5. $\mathbb{P}((t_1, u_1) = (\underline{t}, 0) \mid \text{ID}) = 0$: the expert never makes the mistake of choosing treatment $\underline{t}$ when the problem is major under informative diagnosis.

In an efficient equilibrium, the expert implements treatment $\underline{t}$ to consumer C_1 if his diagnosis is uninformative and consumer C_2 expects $\alpha = 0$. In this case, consumer C_2's belief is

$$\mu = \begin{cases} 1 & \text{if } (t_1, u_1) = (\bar{t}, 1) \\ \\ \frac{1}{2} & \text{if } (t_1, u_1) = (\underline{t}, 1) \\ \\ 0 & \text{if } (t_1, u_1) = (\underline{t}, 0) \end{cases}$$

Under uninformative diagnosis, if the expert follows the efficient strategy and provides $\underline{t}$ to consumer C_1, he expects the treatment to fail, (t_1, u_1) to be $(\underline{t}, 0)$ and, consequently, μ to be zero with probability $h = 2/5$. Given that $\hat{\mu} > 0$, consumer C_2 would not visit the expert if $\mu = 0$. This means that the expert expects consumer C_2 to not visit him with probability 2/5 under these circumstances. However, if the expert deviates and implements treatment $\bar{t}$ to consumer C_1, he makes sure that consumer C_2 receives feedback $(\bar{t}, 1)$ and visits him with probability 1. Therefore, the efficient strategy is not an equilibrium strategy in the presence of consumer feedback. In other words, consumer feedback prevents the expert from choosing the efficient treatment in equilibrium.

1.3 Related literature

This paper contributes to two research areas.

Credence goods. There is an extensive literature on credence goods[11] that investigates the conditions under which experts exploit the informational asymmetries by defrauding consumers (see Dulleck and Kerschbamer (2006) for an overview of the main results in this literature or Balafoutas and Kerschbamer (2020) for a more recent survey with greater focus on experimental results). We contribute to this literature by introducing consumer feedback. The feedback mechanism constitutes an additional source of information that can affect consumers' beliefs concerning an expert's attributes. The relevant attribute we consider is diagnosis informativeness. Contrary to most of this literature that assumes the expert is perfectly informed or that he performs a diagnosis that perfectly reveals the severity of the consumer's problem (e.g., Wolinsky (1993), Dulleck and Kerschbamer (2006) or Dulleck et al. (2011)), we follow a recent strand of the literature that allows for imperfect diagnosis: in Liu et al. (2020), the diagnosis provides a signal about the severity of the consumer's problem and the quality of the signal is either perfect or imperfect (with exogenous probabilities) and is private information of the expert; in Bester and Dahm (2018), the diagnosis also provides a signal but the expert has to exert a costly effort to increase its quality; Balafoutas et al. (2020) consider both exogenous and endogenous

[11] Nelson (1970) studied the effects of consumers having limited information about quality. He introduced the notion of goods characteristics and developed a theory of search and experience goods. Darby and Karni (1973) expanded this typology by introducing the notion of credence characteristics. They state (pp.68-69): *"Search qualities are those that can be ascertained in the search process prior to purchase and experience qualities are those that can be discovered only after purchase as the product is used... Credence qualities are those which, although worthwhile, cannot be evaluated in normal use"*.

signal quality. Imperfect diagnosis is not only interesting theoretically, it also has some empirical support[12]. Since our main contribution pertains to the effects of consumer feedback on efficiency in credence goods markets, we choose a less sophisticated model of diagnosis failure than the ones presented in the papers cited above. More specifically, we assume that the diagnosis is either fully informative (with some exogenous probability) so that the expert perfectly learns the severity of the problem faced by each consumer or fully uninformative so that the expert has the same information as consumers[13]. The binary aspect of diagnosis informativeness is not meant to be an accurate representation of diagnosis imperfection in real world applications. Instead, it is a useful abstraction that helps reveal the effects of consumer feedback in a tractable way.

Consumer feedback and reputation. Consumer feedback has gained growing attention as an important driver of purchasing decisions. This is notably due to the massive expansion of online platforms where consumers can read the feedback of previous consumers before making a purchase. In the last two decades, reputation systems, in a broad sense, have become the focus of an active area of research in economics (see Dellarocas (2003) for a comprehensive overview of this topic). We contribute to this literature by studying a feedback mechanism in credence goods markets[14]. To the best of our knowledge, this is a novel theoretical contribution[15]. As in Shin et al. (2022), we allow prices, which are determined endogenously, to be affected by consumer feedback. More precisely, the monopolistic expert anticipates consumer feedback and strategically determines prices that guarantee the participation of all consumers. We restrict attention to a fixed-price policy but we show in Section 5.1 that our result still holds when prices can change from one consumer to another. We differ from the existing literature in the way we model consumer feedback. In most of the existing literature, each consumer reports a rating which is typically a number that reflects her quality perception (see Shin et al. (2022), Mostagir and Siderius (2022) or Ifrach et al. (2019)). Ratings offer a coarse and subjective representation of the information that consumers can reveal in their feedback. In the case of credence goods, this information may include the received treatment and its outcome as described in the motivating example. We choose to model consumer feedback as containing this pair of objective pieces of information. In this sense, we depart from the existing literature but the unique characteristics of credence goods justify this choice. In particular, there is no clear ranking of the possible values that this feedback can take and as we show in Section 4, their interpretation depends on endogenous factors such

[12] For instance, Schneider (2012) highlights in a field experiment that some basics defects of a car are not detected by mechanics through diagnosis.

[13] For instance, in the case of auto repair, one can imagine that the scanner used by the mechanic to diagnose the car is outdated or insufficiently updated and is inadequate to detect some problems.

[14] The economic analysis of feedback (and in particular online feedback) is primarily empirical. Some seminal papers analyze the effects of online feedback on sellers' reputation for search goods or experience goods. See Cabral (2012) for an overview.

[15] Mimra et al. (2016) also introduce consumer feedback in an experimental study with a focus on the effects of different price regimes. They extend the work of Dulleck et al. (2011) by introducing public histories whereby consumers observe past prices and treatment outcomes.

as treatment strategies. Therefore, the feedback we propose cannot be translated into a standard rating system.

One of the aims of the literature on feedback mechanisms is to model the dynamics of consumers learning about sellers' characteristics or products' quality under different ratings systems. For instance, Acemoglu et al. (2019) develop a model of learning from online reviews where they compare the efficiency of two different rating systems (*full history* and *summary statistics*) in terms of speed of learning. We consider a setting where consumers have access to the full history of feedback and we investigate the incentives for a monopolistic expert to defraud them in comparison to a benchmark case without consumer feedback.

We study the strategic interaction between a feedback system, prices and the reputation of a monopolistic expert. In our model, the expert's reputation concerns the informativeness of his diagnosis. More precisely, the expert uses a technology (or a methodology) which can fail and lead to a situation where he has the same information as consumers. Each consumer feedback gives information about diagnosis informativeness and the expert may overtreat consumers in order to avoid a failure of treatment which would reveal that his diagnosis is uninformative to consumers. By adopting this fraudulent behavior, he manages his reputation and by choosing strategic prices, he guarantees the participation of all consumers. Hence, our paper is closely related to the literature on reputation management where an agent has a belief about a characteristic of another agent and this belief changes over time depending on the history (see Bar-Isaac et al. (2008) or Dellarocas (2006) for an overview).

In the following section, we present our model. Section 3 is dedicated to results in the absence of consumer feedback. Section 4 introduces consumer feedback, its effects on consumers' beliefs and the main result regarding the inefficiency it induces. We discuss several extensions in Section 5 and we conclude in Section 6.

2 The model

2.1 The standard credence good problem

We consider a standard credence good problem where a monopolistic expert (E) *potentially* knows more about the good or service that a consumer needs than the uninformed consumer herself (see DK06). The consumer can visit the expert who may be able to detect the severity of the problem by performing a *costless* diagnosis. The literature on credence goods focuses on the inefficiencies that arise when the expert decides to exploit the information asymmetry by defrauding the consumer. We study the same problem in a modified setting where each consumer provides feedback on her experience with the expert to all future consumers.

More precisely, the market is composed of n consumers with $n \geq 2$. For $k = 1, 2, \ldots, n$, consumer C_k faces a problem θ_k which can be major $\overline{\theta}$ or minor $\underline{\theta}$. Consumer C_k is uncertain about the severity of her problem but she knows the prior probability distribution. Let h be the prior probability that the problem is major, i.e., $\mathbb{P}(\theta_k = \overline{\theta}) = h$ and $\mathbb{P}(\theta_k = \underline{\theta}) = 1 - h$, with $h \in (0, 1)$. We work with the *commitment* assumption of DK06 that states that if the consumer visits the expert, she is committed to undergo the recommended treatment. In this case, the expert has to choose and provide treatment $t_k \in \{\underline{t}, \overline{t}\}$ at cost $c(t_k)$ with $\underline{c} = c(\underline{t})$ and $\overline{c} = c(\overline{t})$ such that $0 \leq \underline{c} < \overline{c}$, for price $p(t_k)$ with $\underline{p} = p(\underline{t})$ and $\overline{p} = p(\overline{t})$. Treatment $\overline{t}$ is the *expensive treatment* whereas treatment $\underline{t}$ is the *cheap treatment*. We denote by $\Delta c = \overline{c} - \underline{c}$ the difference between the costs of both treatments.

The expert's payoff with consumer C_k is given by $p(t_k) - c(t_k)$ which is the difference between the price $p(t_k)$ that consumer C_k pays for treatment t_k and the associated cost $c(t_k)$. Following DK06, we refer to this difference as the *markup*. The consumer C_k's payoff is the difference between his gross utility $u(\theta_k, t_k)$ which depends on the severity of his problem and the received treatment, and the price $p(t_k)$. Gross utility $u(\theta_k, t_k)$ is such that

$$u(\theta_k, t_k) = \begin{cases} 0 & \text{if } \theta_k = \overline{\theta} \text{ and } t_k = \underline{t} \\ v & \text{otherwise} \end{cases}$$

where $v > 0$. As usual in credence good models, this utility function expresses the fact that the expensive treatment $\overline{t}$ always solves the problem of consumer C_k whatever its severity whereas the cheap treatment $\underline{t}$ only solves the minor problem $\underline{\theta}$. We call *appropriate treatment* the one that fixes the consumer's problem at the lowest cost. Treatment $\underline{t}$ (respectively, $\overline{t}$) is the appropriate treatment for the minor problem $\underline{\theta}$ (respectively, major problem $\overline{\theta}$). Consumer C_k receives payoff $v - p(t_k)$ if treatment t_k solves her problem and $-p(t_k)$ otherwise. As in DK06, we assume that $v - \overline{c} > 0$ so that treatment generates a positive surplus in all cases. This implies that it is always efficient to treat every consumer.

Finally, since the prior probability h to face a major problem does not differ from a consumer to another and each consumer has the same valuation v, the *homogeneity* assumption of DK06 is satisfied in our setting. Moreover, we also work with the *verifiability* assumption of DK06 which states that the consumer observes the received treatment. This assumption rules out the problem of overcharging since the expert cannot charge the price $\overline{p}$ when treatment $\underline{t}$ is provided.

2.2 Diagnosis informativeness

An important assumption generally made in the theoretical literature (e.g., Wolinsky (1993), Dulleck and Kerschbamer (2006) or Dulleck et al. (2011)) is that the expert can perfectly diagnose the consumers' problems. As a consequence, the diagnosis always reveals the severity of the problem faced by a consumer. In this paper, we drop this assumption by considering the possibility of unsuccessful diagnosis. More precisely, we assume that the expert uses a diagnosis methodology (or technology) that can fail with probability $1 - \lambda$ in which case no additional information about θ_k is observed and the expert has the same information as consumer C_k's. Alternatively, with probability λ, the diagnosis is successful and the expert perfectly learns the severity of the problem faced by consumer C_k. In this case, he is able to perfectly identify the necessary treatment without making errors. The result of a diagnosis is private information of the expert.

In the case of unsuccessful diagnosis, the expert can make two types of errors: either he recommends and provides treatment $\bar{t}$ although the consumer only has a minor problem or he recommends and provides treatment $\underline{t}$ while the consumer has a major problem. In order to simplify the analysis, we assume that diagnosis informativeness does not change from one consumer to another. In other words, if the diagnosis fails (respectively, succeeds) for consumer C_1 then it fails (respectively, succeeds) for all consumers. By making this assumption, we neglect the learning effects induced by the repeated interaction with consumers and, thus, the possibility for the expert to improve the informativeness of his diagnosis methodology. We discuss this assumption in Section 5.2.

In DK06, the diagnosis is informative with certainty which corresponds to the case where $\lambda = 1$. In our setting, the diagnosis can fail which may lead the expert to undertreat or overtreat consumers by error. Therefore, we drop the *liability* assumption introduced by DK06 which states that the expert cannot provide treatment $\underline{t}$ if treatment $\bar{t}$ is needed.

2.3 Consumer feedback

Let us now introduce the notion of consumer feedback. Consumer feedback is information provided by a consumer about her *experience* with the expert. We reduce the experience to the treatment recommended and provided by the expert and its outcome, i.e., whether it solved the problem or not. These two elements reveal information about the matching between the severity of the consumer's problem and the treatment she received.

Thus, consumer C_k's feedback is the pair $(t_k, u(\theta_k, t_k))$[16] and can take only one of three possible values: $(\bar{t}, v)$, $(\underline{t}, v)$ and $(\underline{t}, 0)$. It is impossible to have $(\bar{t}, 0)$ because treatment $\bar{t}$ fixes both minor and major problems. Feedback $(\underline{t}, v)$ reveals that the expert provided the appropriate treatment $\underline{t}$ for the consumer's problem which was necessarily minor. On the contrary, feedback $(\underline{t}, 0)$ reveals that treatment $\underline{t}$ was not the appropriate treatment for the consumer's problem which was necessarily major. Feedback $(\bar{t}, v)$ reveals that the consumer's problem was fixed but is not sufficient to infer its severity. We assume that each feedback is publicly observable.

We consider a sequence of homogeneous consumers (same values of parameters h and v) indexed by $k = 1, 2, \ldots, n$. Consumer C_k observes the treatment and the corresponding outcome for every consumer up to C_{k-1}. Let $\mathcal{H}_{k-1}$ denote the feedback history up to consumer C_{k-1}. Note that consumer C_1 observes no feedback since she is the first consumer. We set $\mathcal{H}_0 = \emptyset$.

The observation of $\mathcal{H}_{k-1}$ gives consumer C_k information about diagnosis informativeness. More precisely, using feedback history $\mathcal{H}_{k-1}$, she can update her belief about diagnosis informativeness. Let μ_k denote consumer C_k's belief about diagnosis informativeness, defined as follows:

$$\mu_k = \mathbb{P}(\text{ID} \mid \mathcal{H}_{k-1}).$$

[16] Note that consumers do not observe θ_k directly.

Using Bayes rule, we establish the following recurrence relation for consumers' beliefs:

$$\mu_k = \frac{\mu_{k-1}\mathbb{P}((t_{k-1}, u_{k-1}) \mid \text{ID})}{\mu_{k-1}\mathbb{P}((t_{k-1}, u_{k-1}) \mid \text{ID}) + (1 - \mu_{k-1})\mathbb{P}((t_{k-1}, u_{k-1}) \mid \text{UD})} \tag{2}$$

where (t_{k-1}, u_{k-1}) is consumer C_{k-1}'s feedback. t_{k-1} is the treatment consumer C_{k-1} received and $u_{k-1} = u(\theta_{k-1}, t_{k-1})$ is her utility from treatment. As we show below, the belief μ_k determines whether consumer C_k visits the expert or not. If so, she generates a new feedback and the feedback history becomes $\mathcal{H}_k = \mathcal{H}_{k-1} \cup \{(t_k, u(\theta_k, t_k))\}$. If not, the game ends and payoff is equal to zero for the expert and consumer C_k.

3 Efficiency in the absence of consumer feedback

In this section, we present the game (in extensive form) that models the interaction between the monopolistic expert and each consumer. As stated above, our goal is to study the impact of consumer feedback on equilibrium behavior and outcome. In order to do so, we first consider a benchmark case without feedback. In this setting, we determine the efficient treatment and we show that it coincides with the equilibrium treatment.

In the absence of consumer feedback, every consumer has the same belief about diagnosis informativeness (given by the prior probability λ) so that we can restrict attention to the case with one consumer ($n = 1$). For simplicity, we drop the subscript 1 in this section. The timing of the game can be summarized as follows:

1. E announces prices $(\underline{p}, \overline{p})$.
2. Nature draws diagnosis informativeness with $\lambda = \mathbb{P}(\text{ID}) = 1 - \mathbb{P}(\text{UD})$.
3. C observes prices and decides whether to visit E or not.
4. If C does not visit E, the game ends and both C and E receive a zero payoff.
   If C decides to visit E,
   (i) Nature draws θ with $h = \mathbb{P}(\theta = \overline{\theta}) = 1 - \mathbb{P}(\theta = \underline{\theta})$.
   (ii) If the diagnosis is informative, E observes θ. Otherwise, E observes nothing.
   (iii) E chooses and implements a treatment $t \in \{\underline{t}, \overline{t}\}$.
   (iv) E gets payoff $p(t) - c(t)$ and C gets payoff $u(\theta, t) - p(t)$.

Figure 1 gives a representation of this game in extensive form where the expert's payoff appears first in each vector.

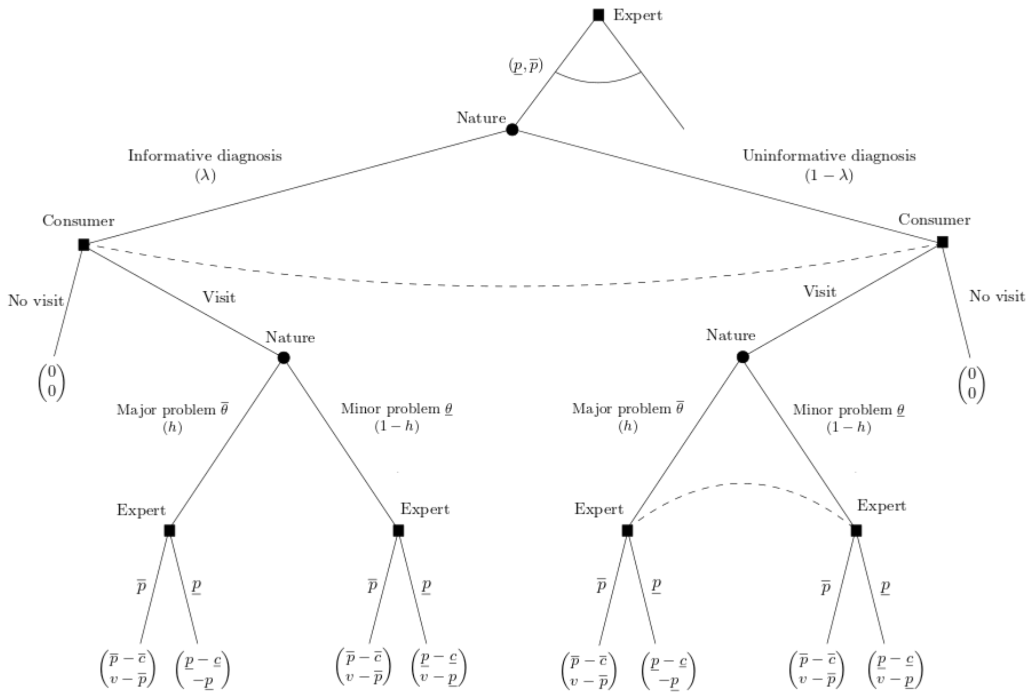

Figure 1: Extensive form of the game

The expert announces his prices without knowing whether his diagnosis is going to be informative or not. This assumption simplifies our analysis, by allowing us to ignore the possibility of signaling diagnosis informativeness through prices, and is justified insofar as we aim to study the effect of consumer feedback alone. We discuss this assumption in Section 5.1.

Nature draws diagnosis informativeness which is not observed by the consumer who has a single information set at which she chooses whether to visit the expert. Note that, as in DK06, the consumer observes the expert's prices before making this decision. If the consumer visits the expert, the commitment assumption prevents her from rejecting the treatment that is chosen by the expert. In this case, Nature draws the severity θ and the expert provides a treatment. Under informative diagnosis, the expert has two information sets corresponding to the two possible values of θ. Under uninformative diagnosis, he has a single information set because he does not observe θ. Note that diagnosis informativeness has no direct effect on payoffs which only depend on problem severity and treatment.

Even though Figure 1 gives the extensive form for the case where there is only one consumer ($n = 1$), the results of this section hold for any number of consumers. In our setting, the expert announces his prices only once and Nature draws diagnosis informativeness only once. Thus, each consumer joins the game at stage 3. In this section, treatment and outcome of each consumer are not revealed to the others and remain private information of the consumer and the expert.

3.1 The efficient treatment

The efficient treatment is the treatment that maximizes the expected total surplus given the available information. If the consumer receives treatment t for a problem θ, the total surplus is $u(\theta, t) - c(t)$. Let r denote the diagnosis result. If the diagnosis is informative, we have $r = \theta$. However, if it is uninformative, we write $r = \emptyset$. Thus, r is an element of the set $\{\overline{\theta}, \underline{\theta}, \emptyset\}$. Let $t^e(r)$ denote the efficient treatment, i.e., the treatment that maximizes the expected total surplus given r. We can readily show that $t^e(\underline{\theta}) = \underline{t}$, $t^e(\overline{\theta}) = \overline{t}$ and

$$t^e(\emptyset) = \begin{cases} \underline{t} & \text{if } \mathbb{E}_\theta(u(\theta, \underline{t}) - \underline{c}) > \mathbb{E}_\theta(u(\theta, \overline{t}) - \overline{c}), \text{i.e., if } h < \Delta c/v \\ \overline{t} & \text{if } h \geq \Delta c/v \end{cases} \tag{3}$$

The efficient treatment is the appropriate treatment if the diagnosis is informative. Otherwise, it is $\underline{t}$ for small h and $\overline{t}$ for large h. The threshold $\Delta c/v$ is strictly between 0 and 1 due to the assumption $0 \leq \underline{c} < \overline{c} < v$. Under uninformative diagnosis, Δc can be interpreted as the cost of guaranteeing that the treatment solves the consumer's problem (using treatment $\overline{t}$ instead of $\underline{t}$). The smaller this cost is relative to the utility gain from successful treatment v, the wider the interval of values of h such that treatment $\overline{t}$ is the efficient one. Note that, as stated in Section 2.1, it is never efficient to not treat the consumer's problem in this setting.

The efficient treatment coincides with that of DK06 for $\lambda = 1$. Moreover, our definition of efficiency is equivalent to that of Balafoutas et al. (2020) when applied to our setting. They define the efficient treatment as the one that minimizes the generalized cost which is the sum of the treatment cost and the loss of consumer utility if the treatment fails.

Overtreatment occurs when the expert provides treatment $\overline{t}$ while the efficient treatment is $\underline{t}$. Similarly, undertreatment occurs when the expert provides treatment $\underline{t}$ while the efficient treatment is $\overline{t}$. Although the definitions of these two forms of inefficiency are stated differently in DK06, our definitions are adapted to the case where diagnosis can be uninformative and coincide with theirs when $\lambda = 1$.

3.2 Efficiency in equilibrium

In the present game, a strategy profile is a tuple $((\underline{p}, \overline{p}, t(.)), d(.))$ where *(i)* $\underline{p} = p(\underline{t})$ and $\overline{p} = p(\overline{t})$ are the prices announced by the expert, *(ii)* t is the expert's treatment decision as a function of diagnosis result r in $\{\overline{\theta}, \underline{\theta}, \emptyset\}$ and *(iii)* d is the consumer's decision to visit the expert or not as a function of prices $(\underline{p}, \overline{p})$.

We choose the Subgame Perfect Equilibrium in pure strategies as a solution concept and, as in DK06, we assume that the expert chooses the efficient treatment (i.e., treatment $t^e(r)$) if he is indifferent between $\underline{t}$ and $\overline{t}$.

The expert's treatment decision depends solely on his payoff $p(t) - c(t)$ independently of the consumer's problem θ. If markups are different, the expert strictly prefers the treatment with the highest markup. However, under equal markups, the expert is indifferent between treatments and chooses the efficient one. The consumer can perfectly anticipate this behavior once she has observed the prices. Her decision to visit the expert or not depends on whether her expected payoff from treatment is non-negative given the announced prices $(\underline{p}, \overline{p})$ and the expert's anticipated treatment decision. If prices are such that treatment $\overline{t}$ has a strictly higher markup than treatment $\underline{t}$, the consumer expects the expert to choose treatment $\overline{t}$ regardless of the result of his diagnosis. Under these circumstances, the consumer is guaranteed to receive utility v and pay $\overline{p}$ which means that her payoff from treatment is $v - \overline{p}$ with certainty. Similarly, if $\underline{t}$ has a strictly higher markup than treatment $\overline{t}$, the consumer expects the expert to choose treatment $\underline{t}$ regardless of the result of his diagnosis. In this case, the treatment works only if the problem is minor, i.e., with probability $1-h$, which implies that the consumer's expected payoff from treatment is $(1-h)v - \underline{p}$. Finally, if both treatments have the same markup, i.e., if $\underline{p} - \underline{c} = \overline{p} - \overline{c}$, the consumer expects the efficient treatment t^e which depends on diagnosis result r. Given that she expects the diagnosis to be informative with probability λ, her expected payoff from treatment can be expressed as follows:

$$\begin{cases} \lambda(h(v-\overline{p}) + (1-h)(v-\underline{p})) + (1-\lambda)((1-h)v - \underline{p}) & \text{if } h < \Delta c/v \\ \lambda(h(v-\overline{p}) + (1-h)(v-\underline{p})) + (1-\lambda)(v-\overline{p}) & \text{if } h \geq \Delta c/v \end{cases}$$

Using these expressions, we can readily derive the consumer's decision in equilibrium, given by $\tilde{d}(.)$ such that $\tilde{d}(\underline{p}, \overline{p})$ is to visit the expert if and only if one of the following conditions holds

(i) $\overline{p} - \overline{c} > \underline{p} - \underline{c}$ and $\overline{p} \leq v$;

(ii) $\underline{p} - \underline{c} > \overline{p} - \overline{c}$ and $\underline{p} \leq (1-h)v$;

(iii) $\overline{p} - \overline{c} = \underline{p} - \underline{c}$ and $\underline{p} \leq \begin{cases} (1-h)v + h(v-\Delta c)\lambda & \text{if } h < \Delta c/v \\ (v-\Delta c) + \Delta c(1-h)\lambda & \text{if } h \geq \Delta c/v \end{cases}$.

Given the consumer's equilibrium strategy $\tilde{d}$, we show that the equilibrium treatment is efficient, we determine equilibrium prices and we show that the consumer visits the expert on equilibrium path. These results are summarized in Proposition 1.

Proposition 1 *In the absence of consumer feedback, the unique equilibrium* $((\underline{p}^*, \overline{p}^*, t^*(.)), d^*)$ *is an equal markup equilibrium* ($\underline{p}^* - \underline{c} = \overline{p}^* - \overline{c}$) *where C visits E and E implements the efficient treatment:*

$$\underline{p}^* = \begin{cases} (1-h)v + h(v-\Delta c)\lambda & \textit{if } h < \Delta c/v \\ (v-\Delta c) + \Delta c(1-h)\lambda & \textit{if } h \geq \Delta c/v \end{cases}, \ \overline{p}^* = \underline{p}^* + \Delta c, \ t^* = t^e, \ \textit{and } d^* = \tilde{d} \quad (4)$$

Proof. See Appendix. ■

Equilibrium prices are such that the expert captures the expected total surplus in its entirety. Therefore, it is optimal for him to choose the efficient treatment which maximizes this surplus, by definition.

Proposition 1 generalizes[17] Lemma 1 of DK06 in a framework where the expert's diagnosis can be uninformative. DK06's result can be recovered by setting $\lambda = 1$. More importantly, it provides a benchmark case where the equilibrium is efficient which allows us to highlight the loss of efficiency caused by consumer feedback in the next section.

4 The effects of consumer feedback on efficiency

In this section, we study the case where consumer C_k observes the feedback of all previous consumers, collected in $\mathcal{H}_{k-1}$, before deciding whether to visit the expert or not. The feedback that each consumer provides contains the treatment she received and its outcome, i.e., whether it solved her problem or not. Consequently, the timing of the game is modified as follows:

1. Expert (E) announces prices $(\underline{p}, \overline{p})$.
2. Nature draws diagnosis informativeness with $\lambda = \mathbb{P}(\text{ID}) = 1 - \mathbb{P}(\text{UD})$.

For $k = 1, 2, \dots, n$

3. Consumer C_k observes prices and $\mathcal{H}_{k-1}$ and decides whether to visit E or not.
4. If C_k does not visit E, period k ends and both C_k and E receive a zero payoff. If C_k decides to visit E,
   (i) Nature draws θ_k with $h = \mathbb{P}(\theta_k = \overline{\theta}) = 1 - \mathbb{P}(\theta_k = \underline{\theta})$.
   (ii) If diagnosis is informative, E observes θ_k. Otherwise, E observes nothing.
   (iii) E chooses and implements a treatment $t_k \in \{\underline{t}, \overline{t}\}$.
   E's period k payoff: $p(t_k) - c(t_k)$
   C_k's payoff: $u(\theta_k, t_k) - p(t_k)$

As in Section 3, each consumer joins the game at stage 3. However, in this section, each consumer observes treatment and outcome of all previous consumers before deciding whether to visit the expert or not. Feedback provided by previous consumers constitutes a public history that each consumer uses to update her belief about diagnosis informativeness.

In this context, we show that consumer feedback can lead to inefficiency in the form of overtreatment. More precisely, we determine the equilibrium of the game and characterize the conditions under which this kind of inefficiency arises. Intuitively, the expert has an incentive to overtreat (i.e., choose $\overline{t}$ while $\underline{t}$ is the efficient treatment) if diagnosis is uninformative in order to avoid a failure of treatment that would negatively impact his reputation in the eyes of future consumers. The efficient treatment is defined in the same way as in Section 3.1 since it only depends on the result of the diagnosis and is not affected by the presence of consumer feedback.

[17] To be more precise, it generalizes the result only in the monopoly case.

For simplicity, we assume that, under equal markups, the expert chooses the efficient treatment if his diagnosis is informative. Although restrictive, this assumption is perfectly reasonable and does not weaken our result because it eliminates one potential source of inefficiency. This assumption seems to be justifiable for at least two reasons. First, the result of the diagnosis may be discoverable at a later date which may allow the consumer to sue the expert for knowingly undertreating her. This creates an incentive for the expert to implement the efficient treatment if the diagnosis is informative. Second, we want to illustrate the inefficiency that consumer feedback can generate and this assumption precludes inefficiency when the diagnosis is informative under equal markups, which strengthens our result. Note that under different markups, we allow the expert to choose the treatment strategically even if his diagnosis is informative.

Figure 2 gives a representation of this game in extensive form, under equal markups, where the expert's payoff appears first in each vector.

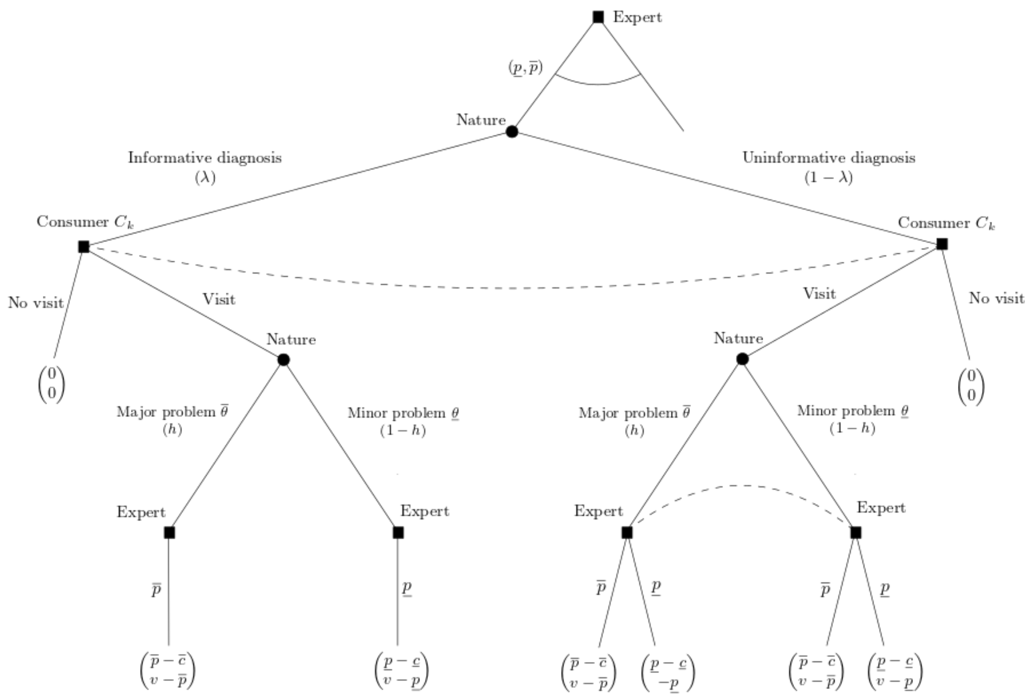

Figure 2: Extensive form of the game under equal markups

The extensive form of Figure 2 is almost identical to that of Figure 1. The only difference is that the expert can only choose the appropriate (and efficient) treatment under informative diagnosis and equal markups. Under different markups, the extensive form of the game is given by Figure 1.

4.1 Beliefs

As explained in Section 4.2, consumers' beliefs are relevant only under equal markups. Consequently, we assume equal markups in this section so that the expert chooses the efficient treatment under informative diagnosis. In the extensive form game of Figure 2, the expert's treatment strategy boils down to his treatment decisions under uninformative diagnosis. For k in $\{1, 2, \ldots, n\}$, let $\tau_{UD,k}$ denote his treatment decision with consumer C_k if diagnosis is uninformative. As defined in Section 2.3, $\mu_k = \mathbb{P}(\text{ID} \mid \mathcal{H}_{k-1})$ denotes consumer C_k's belief about diagnosis informativeness and is given by equation 2. We recall that feedback (t_{k-1}, u_{k-1}) is an element of the set $\{(\bar{t}, v), (\underline{t}, v), (\underline{t}, 0)\}$. The assumption that the expert follows his diagnosis if it is informative implies that feedback $(\underline{t}, 0)$ can be observed only under uninformative diagnosis. These observations yield

$$\mu_k = \beta(\mu_{k-1}, \alpha_{UD,k-1}) = \begin{cases} \frac{\mu_{k-1}h}{\mu_{k-1}h+(1-\mu_{k-1})\alpha_{UD,k-1}} & \text{if } (t_{k-1}, u_{k-1}) = (\bar{t}, v) \\ \\ \frac{\mu_{k-1}}{\mu_{k-1}+(1-\mu_{k-1})(1-\alpha_{UD,k-1})} & \text{if } (t_{k-1}, u_{k-1}) = (\underline{t}, v) \\ \\ 0 & \text{if } (t_{k-1}, u_{k-1}) = (\underline{t}, 0) \end{cases} \tag{5}$$

where β gives consumer C_k's belief as a function of consumer C_{k-1}'s belief (μ_{k-1}) and of her expectation of the expert's treatment decision with C_{k-1} under uninformative diagnosis given by $\alpha_{UD,k-1}$ with $\alpha_{UD,k-1} = 0$ if C_k thinks that $\tau_{UD,k-1}$ is $\underline{t}$ and $\alpha_{UD,k-1} = 1$ if she thinks that it is $\bar{t}$. μ_k is computed, using equation 2, in a similar way to consumer C_2's belief in Section 1.2 (see equation 1 where λ corresponds to consumer C_1's belief).

If $\alpha_{UD,k-1} = 0$,

$$\mu_k = \beta(\mu_{k-1}, 0) = \begin{cases} 1 & \text{if } (t_{k-1}, u_{k-1}) = (\bar{t}, v) \\ \\ \mu_{k-1} & \text{if } (t_{k-1}, u_{k-1}) = (\underline{t}, v) \\ \\ 0 & \text{if } (t_{k-1}, u_{k-1}) = (\underline{t}, 0) \end{cases} \tag{6}$$

To illustrate equation 6, we consider the case where $\alpha_{UD,k} = 0$ and $\tau_{UD,k} = \underline{t}$ for all k, i.e., consumers think correctly that if diagnosis is uninformative, the expert chooses treatment $\underline{t}$. Figure 3 is a representation of this case: for k in $\{1, 2, 3\}$ consumer beliefs remain constant and equal to the prior belief as long as their problems are minor because each consumer receives treatment $\underline{t}$, regardless of diagnosis informativeness, and this treatment fixes her problem. However, the first consumer with a major problem (i.e., consumer C_3) receives treatment $\underline{t}$ (respectively, $\bar{t}$) under uninformative diagnosis (respectively, informative diagnosis) and her problem is not fixed (respectively, fixed). Therefore, all following consumers (i.e., for $k > 3$) correctly infer diagnosis informativeness: their belief goes to 1 (respectively, 0) if they observe feedback $(\bar{t}, v)$ (respectively, $(\underline{t}, 0)$).

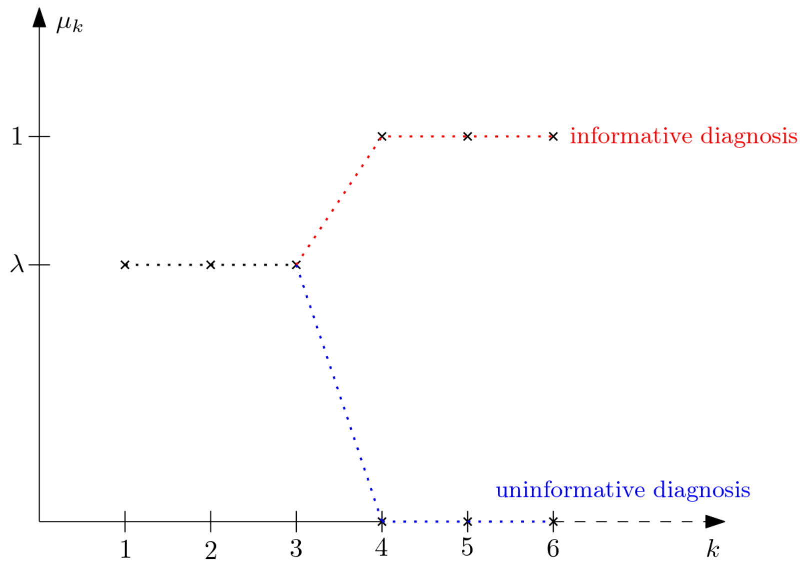

Figure 3: Evolution of beliefs if $\tau_{UD,k} = \underline{t}$ and $\alpha_{UD,k} = 0$ for all k, $\theta_1 = \theta_2 = \underline{\theta}$ and $\theta_3 = \overline{\theta}$

If $\alpha_{UD,k-1} = 1$,

$$\mu_k = \beta(\mu_{k-1}, 1) = \begin{cases} \frac{\mu_{k-1}h}{\mu_{k-1}h+(1-\mu_{k-1})} & \text{if } (t_{k-1}, u_{k-1}) = (\bar{t}, v) \\ 1 & \text{if } (t_{k-1}, u_{k-1}) = (\underline{t}, v) \\ 0 & \text{if } (t_{k-1}, u_{k-1}) = (\underline{t}, 0) \end{cases} \tag{7}$$

To illustrate equation 7, we consider the case where $\alpha_{UD,k} = 1$ and $\tau_{UD,k} = \bar{t}$ for all k, i.e., consumers think correctly that if diagnosis in uninformative, the expert chooses treatment $\bar{t}$. Figure 4 is a representation of this case. Feedback $(\bar{t}, v)$ is interpreted as a bad sign since it is more probable under uninformative diagnosis than under informative diagnosis. As long as the expert is visited by consumers with major problems, each feedback is $(\bar{t}, v)$ and consumer beliefs decrease over time. This is a consequence of the fact that $\mu_{k-1}h/(\mu_{k-1}h + (1 - \mu_{k-1}))$ is strictly smaller than μ_{k-1} for μ_{k-1} in $(0, 1)$. A consumer with a minor problem receives treatment $\bar{t}$ (respectively, $\underline{t}$) under uninformative diagnosis (respectively, informative diagnosis) and her problem is fixed in both cases. Therefore, under informative diagnosis, consumers correctly update their beliefs to 1 after observing feedback $(\underline{t}, v)$ from the first consumer with a minor problem (i.e., consumer C_3). However, consumers cannot learn that diagnosis is uninformative under these circumstances. Instead, beliefs keep decreasing towards 0 without reaching it in this case.

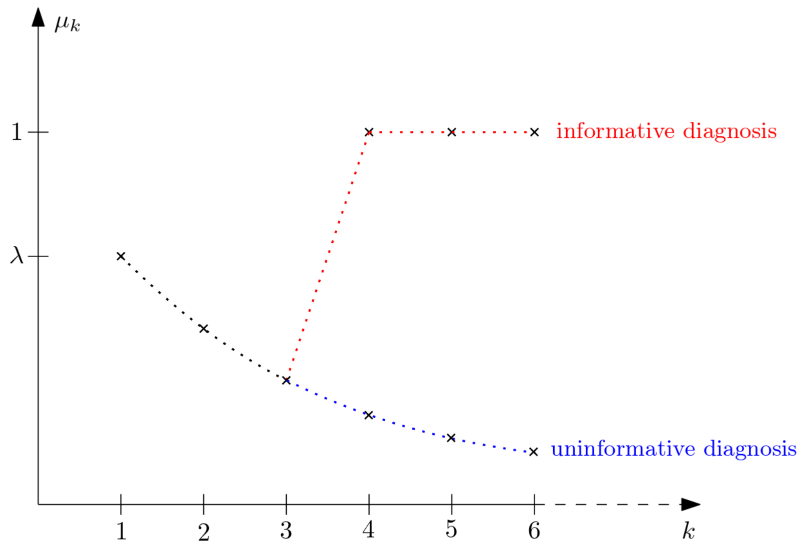

Figure 4: Evolution of beliefs if $\tau_{UD,k} = \bar{t}$ and $\alpha_{UD,k} = 1$ for all k, $\theta_1 = \theta_2 = \bar{\theta}$ and $\theta_3 = \underline{\theta}$

Figures 3 and 4 show the evolution of consumer beliefs when the expert's treatment decision under uninformative diagnosis is the same with all consumers. In addition to being the most simple case to illustrate, this scenario is interesting since, as we show below, it corresponds to the evolution of consumer beliefs on equilibrium path.

4.2 Inefficiency in equilibrium

Under different markups, the maximal price such that the consumer visits the expert is determined in the same way as in the absence of consumer feedback (Section 3.2). This is due to the fact that the expert chooses the highest markup treatment with all consumers regardless of his diagnosis informativeness and result. This is the optimal treatment strategy when facing consumer C_n since she is the last one. Consequently, consumer C_n's decision to visit the expert or not is independent of her belief about diagnosis informativeness. Therefore, the expert does not take into account the effect of consumer C_{n-1}'s treatment outcome on consumer C_n's belief about diagnosis informativeness. This means that it is also optimal for the expert to choose the highest markup treatment when facing consumer C_{n-1}. Using backward induction, we find that, under different markups, this is the expert's optimal treatment strategy with all consumers. Thus, all consumers expect to receive the highest markup treatment, regardless of diagnosis informativeness, if markups are different.

Under equal markups, consumers expect the efficient treatment under informative diagnosis and can expect either treatment under uninformative diagnosis. Consider a consumer who believes diagnosis to be informative with probability μ and expects to receive treatment t_{UD} under uninformative diagnosis. Under equal markups (i.e., $\underline{p} - \underline{c} = \bar{p} - \bar{c}$), her expected payoff from treatment can be expressed as follows, using the same argument as in Section 3.2:

$$\begin{cases} \mu(h(v-\overline{p})+(1-h)(v-\underline{p}))+(1-\mu)((1-h)v-\underline{p}) & \text{if } t_{UD}=\underline{t} \\ \mu(h(v-\overline{p})+(1-h)(v-\underline{p}))+(1-\mu)(v-\overline{p}) & \text{if } t_{UD}=\overline{t} \end{cases}$$

Therefore, the maximal price $\underline{p}$ that this consumer accepts is:

$$\underline{p}^M(\mu, t_{UD}) = \begin{cases} (1-h)v + h(v-\Delta c)\mu & \text{if } t_{UD}=\underline{t} \\ (v-\Delta c) + \Delta c(1-h)\mu & \text{if } t_{UD}=\overline{t} \end{cases} \tag{8}$$

Note that equilibrium prices in the absence of consumer feedback (see Proposition 1) are given by

$$\underline{p}^* = \begin{cases} \underline{p}^M(\lambda, \underline{t}) & \text{if } h < \Delta c/v \\ \underline{p}^M(\lambda, \overline{t}) & \text{if } h \geq \Delta c/v \end{cases}$$

In both cases (with and without feedback), the maximal price $\underline{p}$ that this consumer accepts depends on the treatment received under uninformative diagnosis. The only difference is that she expects to receive the efficient treatment in the absence of feedback under equal markups.

These observations allow us to define the consumer's decision $\hat{d}$ as follows: $\hat{d}(\underline{p}, \overline{p}, \mu, t_{UD})$ is to visit the expert if and only if one of the following conditions holds

(i) $\overline{p} - \overline{c} > \underline{p} - \underline{c}$ and $\overline{p} \leq v$;

(ii) $\underline{p} - \underline{c} > \overline{p} - \overline{c}$ and $\underline{p} \leq (1-h)v$;

(iii) $\overline{p} - \overline{c} = \underline{p} - \underline{c}$ and $\underline{p} \leq \underline{p}^M(\mu, t_{UD})$.

In the present game, a strategy profile is a tuple $((\underline{p}, \overline{p}, \tau_{UD}), d(.))$ where *(i)* $\underline{p} = p(\underline{t})$ and $\overline{p} = p(\overline{t})$ are the prices announced by the expert, *(ii)* $\tau_{UD} = (\tau_{UD,k})_{k=1,2,\ldots,n}$ describes the expert's treatment decision under uninformative diagnosis with each consumer and *(iii)* $d = (d_k)_{k=1,2,\ldots,n}$ gives consumer C_k's decision to visit the expert or not as a function of prices $(\underline{p}, \overline{p})$. A Perfect Bayesian Equilibrium is given by a strategy profile together with consumer beliefs $\mu = (\mu_k)_{k=1,2,\ldots,n}$ about diagnosis informativeness. We focus on equal markup equilibria since different markups unambiguously lead to an inefficient outcome such that the expert provides the highest markup treatment to all consumers regardless of diagnosis informativeness. In Proposition 2, we characterize the unique equal markup equilibrium of the game and it can be readily verified that the expert's payoff in this equilibrium is always greater than the maximum payoff he can achieve with different markups. Moreover, the net social surplus in the equal markup equilibrium is higher than its value under different markups.

Proposition 2 *In the presence of consumer feedback, for $n \geq 2$, there exists η_n in $(0, \Delta c/v)$ such that*

$$\eta_2 = \frac{(1-\lambda)\Delta c}{v - \lambda \Delta c} < \frac{\Delta c}{v}, \quad \eta_n < \eta_{n+1} < \frac{\Delta c}{v} \text{ for } n \geq 2, \quad \lim_{n \to +\infty} \eta_n = \frac{\Delta c}{v}$$

and the unique equal markup equilibrium $((\underline{p}^*, \overline{p}^*, \tau^*_{UD}), d^*, \mu^*)$ is such that all n consumers visit E and E implements the efficient treatment except if the diagnosis is uninformative and $\eta_n < h < \Delta c/v$:

- $\underline{p}^* = \begin{cases} \underline{p}^M(0, \underline{t}) & \text{if } 0 < h \leq \eta_n \\ \min\{\underline{p}^M(\tilde{\mu}_{n-1}, \overline{t}), \underline{p}^M(\tilde{\mu}_n, \underline{t})\} & \text{if } \eta_n < h < \Delta c/v \\ \underline{p}^M(\tilde{\mu}_n, \overline{t}) & \text{if } \Delta c/v \leq h < 1 \end{cases}$ *and* $\overline{p}^* = \underline{p}^* + \Delta c$
- $\tau^*_{UD,k} = \begin{cases} \underline{t} & \text{if } 0 < h \leq \eta_n \\ \overline{t} & \text{if } \eta_n < h < 1 \end{cases}$ *for $1 \leq k \leq n-1$ and* $\tau^*_{UD,n} = \begin{cases} \underline{t} & \text{if } 0 < h \leq \Delta c/v \\ \overline{t} & \text{if } \Delta c/v < h < 1 \end{cases}$
- $d^*_k(\underline{p}, \overline{p}) = \hat{d}(\underline{p}, \overline{p}, \mu^*_k, \tau^*_{UD,k})$ *for k in $\{1, 2, \ldots, n\}$*
- $\mu^*_1 = \lambda$ *and* $\mu^*_k = \beta(\mu^*_{k-1}, \mathbf{1}_{\{\tau^*_{UD,k-1} = \overline{t}\}})$ *for k in $\{2, \ldots, n\}$*

where $\tilde{\mu}_k = \frac{\lambda h^{k-1}}{\lambda h^{k-1} + 1 - \lambda}$, $\tilde{\mu}_1 = \lambda$ (i.e., prior belief) and for $k \geq 2$, $\tilde{\mu}_k$ is C_k's belief if she thinks the expert chooses treatment $\overline{t}$ under uninformative diagnosis with consumers C_1 to C_{k-1} and all these consumers actually received treatment $\overline{t}$.

Proof. See Appendix. ■

Proposition 2 is the main result of this article. It states that consumer feedback leads to treatment inefficiency for some parameter combinations. More precisely, for intermediate values of h, namely in $(\eta_n, \Delta c/v)$, the expert overtreats consumers C_1 to C_{n-1} under uninformative diagnosis, i.e., he chooses treatment $\overline{t}$ while the efficient treatment is $\underline{t}$. Consumer C_n receives the efficient treatment because she is the last one which makes the expert indifferent between treatments $\underline{t}$ and $\overline{t}$ since treatment outcome for this consumer has no impact on his payoff.

A notable feature of treatment strategy in equilibrium is that consumers C_1 to C_{n-1} receive the same treatment under uninformative diagnosis. Another important feature of this equilibrium is that prices are chosen so as to guarantee that all consumers visit the expert given the treatment strategy and the evolution of belief that it would generate. In particular, equilibrium prices for h in $(0, \eta_n]$ are such that consumers visit the expert even if they observe a failure of the efficient treatment $\underline{t}$ with a previous consumer. However, these prices are lower than equilibrium prices for h in $(\eta_n, \Delta c/v)$ which are not compatible with the efficient treatment $\underline{t}$ since a failure of treatment in this case would lead all future consumers to decide not to visit the expert. Under these circumstances, the expert chooses to overtreat consumers in order to use these higher prices and receive a greater payoff.

In order to further illustrate Proposition 2, consider the case where there are only two consumers (i.e., $n = 2$). Recall that the efficient treatment is such that

$$t^e(\emptyset) = \begin{cases} \underline{t} \text{ if } 0 < h < \Delta c/v \\ \bar{t} \text{ if } \Delta c/v \leq h < 1 \end{cases} .$$

In equilibrium, consumer C_2 receives the efficient treatment while the treatment received by consumer C_1 under uninformative diagnosis is

$$\tau^*_{UD,1} = \begin{cases} \underline{t} \text{ if } 0 < h \leq \eta_2 \\ \bar{t} \text{ if } \eta_2 < h \leq 1 \end{cases} .$$

As explained above, consumer C_2 receives the efficient treatment because she is the last one. Consumer C_1 does not always receive the efficient treatment because the expert takes into account the effect of her feedback on consumer C_2's belief and decision.

For h in $(\eta_2, \Delta c/v)$, the expert overtreats consumer C_1 under uninformative diagnosis in order to avoid the risk of having consumer C_2 observe a failure of treatment on C_1 which would reveal that the diagnosis is uninformative: consumer C_2 would infer this from feedback $(\underline{t}, 0)$ by consumer C_1 which may lead her to decide not to visit the expert.

Overtreating consumer C_1 in this case allows the expert to charge higher prices than those that the efficient treatment allows. For h in $(\eta_2, \Delta c/v)$, the efficient treatment under uninformative diagnosis is $\underline{t}$ which yields feedback $(\underline{t}, 0)$ with nonzero probability. Thus, in order to guarantee that consumer C_2 visits him regardless of consumer C_1's feedback, the expert sets $\underline{p} = \underline{p}^M(0, \underline{t}) = (1 - h)v$. In fact, this is the maximal $\underline{p}$ that is compatible with the efficient treatment strategy. With any higher $\underline{p}$, the expert would have an incentive to deviate from treatment $\underline{t}$ to treatment $\bar{t}$ with consumer C_1 under uninformative diagnosis in order to avoid losing consumer C_2's visit. If he overtreats consumer C_1 under uninformative diagnosis, the expert is able to charge the price $\underline{p} = \min\{\underline{p}^M(\tilde{\mu}_1, \bar{t}), \underline{p}^M(\tilde{\mu}_2, \underline{t})\}$ which is strictly greater than $(1 - h)v$ for h in $(\eta_2, \Delta c/v)$). $\underline{p}^M(\tilde{\mu}_1, \bar{t})$ is the maximal $\underline{p}$ that consumer C_1 accepts when she anticipates treatment $\bar{t}$ under uninformative diagnosis. $\underline{p}^M(\tilde{\mu}_2, \underline{t})$ is the maximal $\underline{p}$ that consumer C_2 accepts when *(i)* she expects receiving treatment $\underline{t}$ under uninformative diagnosis, *(ii)* she thinks consumer C_1 receives treatment $\bar{t}$ under uninformative diagnosis and *(iii)* consumer C_1 actually received treatment $\bar{t}$. A price $\underline{p}$ equal to the minimum of these two prices guarantees that both consumers visit the expert when they expect treatment under uninformative diagnosis to be $\bar{t}$ for consumer C_1 and $\underline{t}$ for consumer C_2, as long as the expert follows this treatment strategy, because $\tilde{\mu}_2$ is the lowest possible belief for consumer C_2 under these circumstances and $\underline{p}^M(\mu, \underline{t})$ is increasing in μ. Furthermore, the expert has no incentive to deviate from this treatment strategy given these prices.

Figure 5 illustrates the fact that, in equilibrium, consumers C_1 to C_{n-1} are overtreated under uninformative diagnosis if h is in $(\eta_n, \Delta c/v)$.

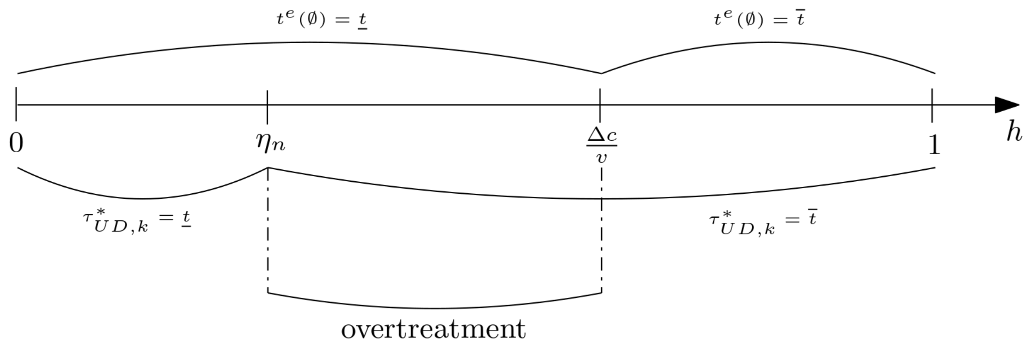

Figure 5: Overtreatment of consumer C_k under uninformative diagnosis in equilibrium for $k = 1, \ldots, n-1$.

Note that, in equilibrium, it is impossible to have simultaneously a price $\underline{p}$ strictly greater than $(1-h)v$ and $\tau^*_{UD,k} = \underline{t}$ for some $k \leq n-1$. The reason is the same as in the case with two consumers. With such a combination of price and treatment strategy, it would be profitable for the expert to deviate to treatment $\overline{t}$ under uninformative diagnosis in order to ensure that consumers after C_k visit him by eliminating the risk of treatment failure.

Since the expert always chooses the efficient treatment in the absence of consumer feedback and surplus is greater under informative diagnosis than under uninformative diagnosis, a greater λ always gives a higher expected surplus.

However, this is not always the case in the presence of consumer feedback for $h < \Delta c/v$. In order to illustrate this effect, we consider the case of two consumers ($n = 2$) but the argument can be extended to any number of consumers. Consider a value of h in $(0, \Delta c/v)$. The expert's treatment decision with consumer C_1 under uninformative diagnosis depends on whether h is smaller or larger than η_2, or equivalently, on whether λ is smaller or larger than $\hat{\lambda}$ where

$$\hat{\lambda} = \frac{\Delta c - hv}{\Delta c(1-h)}.$$

If $\lambda \leq \hat{\lambda}$ (respectively, $\lambda > \hat{\lambda}$), the expert chooses treatment $\underline{t}$ (respectively, $\overline{t}$) for consumer C_1 under uninformative diagnosis. For all λ, the expert chooses the efficient treatment for consumer C_2 under uninformative diagnosis (i.e., treatment $\underline{t}$). Therefore, the expected total surplus is

$$\begin{cases} 2\Big(\lambda(h(v-\overline{c}) + (1-h)(v-\underline{c})) + (1-\lambda)\big((1-h)v - \underline{c}\big)\Big) & \text{if } \lambda \leq \hat{\lambda} \\ 2\lambda(h(v-\overline{c}) + (1-h)(v-\underline{c})) + (1-\lambda)(v - \overline{c} + (1-h)v - \underline{c}) & \text{if } \lambda > \hat{\lambda} \end{cases}$$

Figure 6 illustrates the fact that in the presence of consumer feedback, surplus does not always increase when the probability of an informative diagnosis (i.e., λ) increases. More specifically, surplus is increasing in λ over $[0, \hat{\lambda}]$ and over $(\hat{\lambda}, 1]$ but with a downward discontinuity at $\hat{\lambda}$ which is due to the change in treatment decision under uninformative diagnosis. When λ increases from $\hat{\lambda}$ to $\hat{\lambda} + \varepsilon$ (with small positive ε), the (small) positive effect of a larger probability of informative diagnosis, and thus a larger probability of choosing the appropriate treatment, is dominated by the negative impact of overtreatment under uninformative diagnosis. Starting from a value of λ in $(\lambda', \hat{\lambda}]$, increasing the probability of informative diagnosis can reduce surplus. Similarly, starting from a value of λ in $(\hat{\lambda}, \lambda'')$, surplus can be increased by reducing the probability of informative diagnosis.

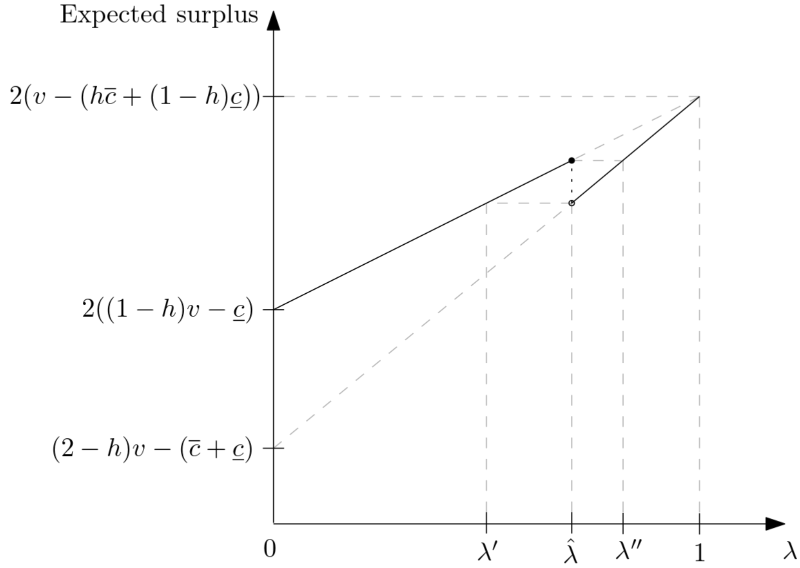

Figure 6: Total expected surplus as a function of λ for a given h in $(0, \Delta c/v)$.

5 Discussion

In this section, we discuss two main assumptions of our model, namely fixed prices and fixed diagnosis informativeness. We further show that consumer feedback does not solve the well-known lemons problem in credence goods markets.

5.1 Variable prices

Throughout the article, we have assumed that prices are the same for all consumers. In this section, we allow the expert to announce different prices for each consumer and we argue that our main result still holds. More precisely, we show that for h in $(0, \Delta c/v)$ and in the presence of consumer feedback, if consumers expect to always receive the efficient treatment, then the expert has an incentive to deviate to overtreatment which implies that the equilibrium outcome is not efficient. This is enough to prove that our result holds because the equilibrium outcome in the absence of consumer feedback is the same as in Section 3: all consumers hold the same belief about diagnosis informativeness so that the expert announces the same prices to everyone. However, there is a subtle difference with our main model that needs to be addressed. Given that the expert announces prices after learning whether his diagnosis is informative or uninformative (starting at the second consumer), it would be possible, in principle, to signal this information through prices. Nevertheless, we choose to keep this discussion consistent with our analysis by assuming that this kind of signaling cannot take place. An alternative interpretation of this choice is that we focus on pooling equilibria only (i.e., equilibria where the expert chooses prices independently of diagnosis informativeness).

For ease of exposition, consider the case of two consumers ($n = 2$). Let h be in $(0, \Delta c/v)$. The first consumer believes that the expert's diagnosis is informative with probability λ. If both consumers expect to receive the efficient treatment then the second consumer believes that the expert's diagnosis is informative with probability μ such that[18]

$$\mu = \begin{cases} 1 & \text{if } (t_1, u_1) = (\bar{t}, v) \\ \\ \lambda & \text{if } (t_1, u_1) = (\underline{t}, v) \\ \\ 0 & \text{if } (t_1, u_1) = (\underline{t}, 0) \end{cases}$$

In this context, the maximum (equal markup) prices that consumer C_1 accepts are such that $\underline{p} = \underline{p}^M(\lambda, \underline{t})$. For consumer C_2, the maximum prices are such that $\underline{p} = \underline{p}^M(\mu, \underline{t})$. Given that $\underline{p}^M(\mu, \underline{t})$ is increasing in μ, the expert can guarantee receiving the highest possible price from consumer C_2, i.e., $\underline{p}^M(1, \underline{t})$ by implementing treatment $\bar{t}$ to consumer C_1. This constitutes a profitable deviation from the efficient treatment strategy. The argument presented here can be extended to more than two consumers.

5.2 Variable diagnosis informativeness

In the main model, we assume that informativeness is a stable property of the expert's diagnosis that does not change from one consumer to the next. In this section, we consider a case where diagnosis informativeness may vary and we argue that our main result still holds.

Assume that the expert's diagnosis is either uninformative as in the main model (with probability $1 - \lambda$) or potentially informative (with probability λ). If the diagnosis is potentially informative, Nature draws diagnosis informativeness every time a new consumer visits the expert according to the following distribution: diagnosis is informative with probability s and uninformative with probability $1 - s$. These random draws are independent. The main model is recovered for $s = 1$.

In the absence of feedback, this new model is formally equivalent to the main model with a modified probability of having an informative diagnosis $\tilde{\lambda} = \lambda s$. This is a consequence of the following observations: *(i)* if markups are different, the expert chooses the treatment with the highest markup regardless of diagnosis informativeness and result, *(ii)* under equal markups, the expert is indifferent between the two treatments and chooses the efficient one. Therefore, the equilibrium of the game is analogous to the one of Proposition 1 where λ has to be replaced with $\tilde{\lambda}$. Importantly, the equilibrium outcome is efficient in this case.

[18] Using equation 6.

When we introduce consumer feedback, we need to modify our analysis in order to account for the two distinct situations where diagnosis is uninformative. The first is the same as in the main model, i.e., when diagnosis is uninformative with all consumers. The second is when diagnosis fails at random while it is potentially informative. We denote UD the former situation and PI the latter one. In this discussion, we restrict attention to the case of two consumers ($n = 2$) as it is sufficient to illustrate the fact that consumer feedback leads to an inefficient outcome for some parameter combinations. We continue to assume that the expert chooses the efficient treatment under informative diagnosis and whenever he is indifferent between the two treatments. Thus, consumer C_2 receives the efficient treatment in all cases (under equal markups). The expert's treatment strategy is given by τ_{UD} and τ_{PI} where τ_{UD} (respectively, τ_{PI}) is the treatment that consumer C_1 receives under UD (respectively, PI). Similarly to the main analysis, we define α_{UD} and α_{PI} to describe consumer C_2's expectation of the expert's treatment decision under UD and PI respectively: for j in $\{UD, PI\}$, $\alpha_j = 0$ (respectively, 1) if C_2 thinks that τ_j is $\underline{t}$ (respectively, $\bar{t}$). We know that C_1 believes the expert's diagnosis to be potentially informative with probability λ (prior probability). After receiving feedback (t_1, u_1) from consumer C_1, consumer C_2 believes the expert's diagnosis to be potentially informative with probability μ where

$$\mu = \begin{cases} \frac{\lambda(sh+(1-s)\alpha_{PI})}{\lambda(sh+(1-s)\alpha_{PI})+(1-\lambda)\alpha_{UD}} & \text{if } (t_1, u_1) = (\bar{t}, v) \\ \\ \frac{\lambda(s+(1-s)(1-\alpha_{PI}))}{\lambda(s+(1-s)(1-\alpha_{PI}))+(1-\lambda)(1-\alpha_{UD})} & \text{if } (t_1, u_1) = (\underline{t}, v) \\ \\ \frac{\lambda(1-s)(1-\alpha_{PI})}{\lambda(1-s)(1-\alpha_{PI})+(1-\lambda)(1-\alpha_{UD})} & \text{if } (t_1, u_1) = (\underline{t}, 0) \end{cases}$$

In the remainder of this discussion, we show that for some values of h, the equilibrium outcome cannot be efficient. Consider h in $(0, \Delta c/v)$ so that the efficient treatment when diagnosis is uninformative is $\underline{t}$. If C_2 thinks that the expert chooses the efficient treatment for C_1 then $\alpha_{PI} = \alpha_{UD} = 0$ and

$$\mu = \begin{cases} 1 & \text{if } (t_1, u_1) = (\bar{t}, v) \\ \\ \lambda & \text{if } (t_1, u_1) = (\underline{t}, v) \\ \\ \frac{\lambda(1-s)}{1-\lambda s} & \text{if } (t_1, u_1) = (\underline{t}, 0) \end{cases}$$

These beliefs differ from those of our main setting only after feedback $(\underline{t}, 0)$. However, we have $\lambda(1-s)/(1-\lambda s) < \lambda$ for λ in $(0, 1)$. Using the same arguments as in our main analysis, we see that the maximum equal markup prices that do not lead the expert to deviate from the efficient treatment strategies are such that

$$\underline{p} = \underline{p}^M \left(\frac{\lambda(1-s)}{1-\lambda s}, \underline{t} \right).$$

We now show that for every s in $(0,1)$ there exists a threshold $\tilde{\eta}_s$ such that for h in $(\tilde{\eta}_s, \Delta c/v)$, the expert can charge higher (equal markup) prices by overtreating consumer C_1 whenever his diagnosis is uninformative. If C_2 correctly anticipates this behavior by the expert then $\alpha_{PI} = \alpha_{UD} = 1$ and[19]

$$\mu = \begin{cases} \frac{\lambda(1-s(1-h))}{1-\lambda s(1-h)} & \text{if } (t_1, u_1) = (\bar{t}, v) \\ \\ 1 & \text{if } (t_1, u_1) = (\underline{t}, v) \end{cases}$$

Using the same arguments as in our main analysis, we find that equal markup prices such that

$$\underline{p} = \min \left\{ \underline{p}^M(\lambda, \bar{t}), \underline{p}^M \left(\frac{\lambda(1-s(1-h))}{1-\lambda s(1-h)}, \underline{t} \right) \right\}$$

guarantee that both consumers visit the expert while the expert overtreats C_1 whenever his diagnosis is uninformative. We observe that, for all λ in $(0,1)$,

$$\frac{\lambda(1-s(1-h))}{1-\lambda s(1-h)} > \frac{\lambda(1-s)}{1-\lambda s}$$

which implies

$$\underline{p}^M \left(\frac{\lambda(1-s(1-h))}{1-\lambda s(1-h)}, \underline{t} \right) > \underline{p}^M \left(\frac{\lambda(1-s)}{1-\lambda s}, \underline{t} \right).$$

Moreover,

$$\underline{p}^M(\lambda, \bar{t}) > \underline{p}^M \left(\frac{\lambda(1-s)}{1-\lambda s}, \underline{t} \right)$$

for all h in $(\tilde{\eta}_s, \Delta c/v)$ where $\tilde{\eta}_s = \frac{(1-\lambda s)^2 \Delta c}{(1-\lambda s(2-s))v - \lambda s^2(1-\lambda)\Delta c}$. Therefore, the equilibrium outcome is not efficient for these values of h.

5.3 The lemons problem in credence goods markets

DK06 show that, under the assumptions of commitment and homogeneity alone, a lemons problem arises whereby the expert chooses treatment $\underline{t}$ regardless of problem severity and charges price $(1-h)v$ if it is higher than $\underline{c}$. Otherwise (i.e., if $(1-h)v < \underline{c}$), the market breaks down. It is legitimate to wonder whether consumer feedback can solve this problem or, at least, reduce inefficiency. As we show below, this is not the case and the equilibrium outcome is the same with and without consumer feedback and it is inefficient.

First, we present the intuition behind Proposition 4 of DK06 which states that the

[19] In this case, we disregard C_2's belief after feedback $(\underline{t}, 0)$ given that it cannot be observed if the expert follows the treatment strategy under consideration. This belief is indeterminate but irrelevant to our argument.

lemons problem arises if assumptions L and V do not hold. In particular, this result mainly a consequence of the absence of verifiability: if the consumer cannot verify which treatment she received, the expert has no incentive to implement treatment $\bar{t}$ because its cost is higher without any additional benefit to him given that the price he charges does not have to match the treatment he implements (overcharging is possible in the absence of verifiability). Even though a failure of treatment reveals to the consumer that she received treatment $\underline{t}$, she cannot protect herself against overcharging precisely because she cannot prove that the price she paid was higher than it should have been. Therefore, in equilibrium, if the consumer visits the expert, he provides treatment $\underline{t}$ and charges the highest price that he announced (i.e., $\max\{\underline{p}, \overline{p}\}$). Without loss of generality, we can restrict attention to an equilibrium where the expert posts the same price (if any) for both treatments making it obvious that he is going to implement treatment $\underline{t}$. The maximum price that a consumer accepts under these circumstances is $(1-h)v$ (the expected value of treatment $\underline{t}$ which fixes only the minor problem). Finally, the expert serves the market if and only if this price is higher than $\underline{c}$, the cost of implementing treatment $\underline{t}$.

This result can be readily extended to our framework in the absence of feedback: uncertainty about diagnosis informativeness does not affect the argument presented above. One might hope that consumer feedback allows for the reduction of inefficiency in this case but we can show that the equilibrium outcome remains unchanged. If she visits the expert, consumer C_n is certain that she is going to receive treatment $\underline{t}$ (because she is the last one which means that the expert is facing the same decision as in the absence of feedback) and would accept to pay at most $(1-h)v$. Consequently, consumer C_n does not care about the history of feedback[20] from previous consumers. Therefore, the expert's treatment decision with consumer C_{n-1} has no impact on consumer C_n's decision which means, once again, that with consumer C_{n-1}, the expert is facing the same decision as in the absence of feedback so that he chooses treatment $\underline{t}$ and this consumer accepts to pay at most $(1-h)v$. By backward induction, we conclude that the equilibrium outcome is unaffected by consumer feedback.

6 Conclusion

In this paper, we introduce consumer feedback in a credence goods model, inspired by DK06. In our framework, consumer feedback generates a learning effect concerning the expert's attributes. Although similar, this kind of learning has to be distinguished from the one described in models of social learning (see Bikhchandani et al. (1992), Banerjee (1992), Welch (1992), or Chamley (2004) for an overview of these models) where learning takes place through the observation of actions taken by others. More precisely, we consider a setting where a finite number of consumers, each facing a problem that can be major or minor, can sequentially visit a monopolistic expert. After making a diagnosis, which either perfectly reveals the severity of the problem faced by each consumer or gives no additional

[20]Note that, in this case, the feedback provided by consumer C_k contains one piece of information, namely u_k, given that she cannot verify the treatment.

information, the expert recommends and provides a treatment. The result of the diagnosis is available only to the expert and consumers only observe the provided treatment and its outcome.

We first consider a benchmark case with no feedback. In this situation, the expert plays a new game with each consumer and always provides the efficient treatment. We then introduce consumer feedback. More precisely, we assume that, after visiting the expert, each consumer reveals the treatment she received and its outcome, i.e., whether her problem was fixed or not. This generates a public history available to all consumers (for instance, through an online platform dedicated to the relevant area of expertise). Each consumer uses the feedback from all previous consumers to update her belief about the informativeness of the expert's diagnosis. She then decides whether to visit him or not. The expert has to take into account the effect of each feedback on consumers' beliefs and decisions when he chooses his prices and treatment strategy. In this setting, we show that consumer feedback can be a new source of inefficiencies and, more specifically, a source of overtreatment. Our result is closely related to the strategic effects of consumer feedback on the expert's behavior. Thus, in our theoretical framework, consumer feedback has a negative impact on efficiency even though it provides additional information to consumers. Our result is in line with the one of Morris and Shin (2002) where public information can be detrimental to social welfare.

Appendix

Proof of Proposition 1. We have already established that the consumer's decision whether to visit the expert is determined by $\tilde{d}$. The expert anticipates this and announces prices that maximize his payoff while guaranteeing that the consumer visits him. Among all price pairs $(\underline{p}, \overline{p})$ such that $\overline{p} - \overline{c} > \underline{p} - \underline{c}$, the ones that maximize the expert's payoff are such that $\overline{p} = v$ and give him the payoff $v - \overline{c}$. Similarly, among all price pairs $(\underline{p}, \overline{p})$ such that $\underline{p} - \underline{c} > \overline{p} - \overline{c}$, the ones that maximize the expert's payoff are such that $\underline{p} = (1-h)v$ and give him an payoff $(1-h)v - \underline{c}$. In both cases, we took the maximum price such that the consumer visits the expert and computed his payoff using the fact that he would later select the treatment with the highest markup. Finally, among all price pairs $(\underline{p}, \overline{p})$ with equal markups, i.e., $\underline{p} - \underline{c} = \overline{p} - \overline{c}$, the one that maximizes the expert's payoff is such that

$$\underline{p} = \begin{cases} (1-h)v + h(v - \Delta c)\lambda & \text{if } h < \Delta c/v \\ (v - \Delta c) + \Delta c(1-h)\lambda & \text{if } h \geq \Delta c/v \end{cases}$$

and gives him the payoff

$$\begin{cases} (1-h)v + h(v-\Delta c)\lambda - \underline{c} = ((1-h)v - \underline{c}) + h(v - \Delta c)\lambda & \text{if } h < \Delta c/v \\ (v - \Delta c) + \Delta c(1-h)\lambda - \underline{c} = (v - \overline{c}) + \Delta c(1-h)\lambda & \text{if } h \geq \Delta c/v \end{cases}.$$

We conclude that the expert's payoff is maximized using this last price pair because $((1-h)v - \underline{c}) + h(v - \Delta c)\lambda > (1-h)v - \underline{c} > v - \overline{c}$ if $h < \Delta c/v$ and $(v - \overline{c}) + \Delta c(1-h)\lambda > v - \overline{c} \geq (1-h)v - \underline{c}$ if $h \geq \Delta c/v$. The equilibrium treatment strategy follows from the assumption that the expert chooses the efficient treatment if he is indifferent, which he is given these prices. ■

Proof of Proposition 2. In order to prove this result, we prove the following sequence of claims. Let $((\underline{p}^*, \overline{p}^*, \tau^*_{UD}), d^*, \mu^*)$ be an equal markup equilibrium.

Claim 1 states consumers' beliefs about diagnosis informativeness. Claim 2 pertains to consumers' decisions to visit the expert. For equilibrium prices and treatment strategy when h is in $(0, \Delta c/v)$, see claims 3 to 11. For equilibrium prices and treatment strategy when h is in $[\Delta c/v, 1)$, see claims 3 and 4 and claims 13 to 15. The threshold η_n is identified in claim 10 and studied in claim 12.

1. $\mu^*_1 = \lambda$ *and* $\mu^*_k = \beta(\mu^*_{k-1}, \mathbf{1}_{\{\tau^*_{UD,k-1} = \overline{t}\}})$ *for* k *in* $\{2, \ldots, n\}$.

   The first consumer's belief is given by the prior belief λ. On equilibrium path, beliefs are updated using Bayes rule and are given by function β as detailed in Section 4.1 under the condition that consumers anticipate correctly the equilibrium treatment strategy so that, for all $k \geq 2$, $\alpha_{UD,k-1}$ is equal to 1 if $\tau^*_{UD,k-1} = \overline{t}$ and equal to 0 otherwise. The only possible off-equilibrium event is the observation of feedback $(\underline{t}, 0)$ while $\tau^*_{UD,k-1} = \overline{t}$. However, under the assumption that the expert chooses the efficient treatment when his diagnosis is informative, feedback $(\underline{t}, 0)$ can only be observed under uninformative diagnosis and is interpreted as such (see equation 5). Therefore, beliefs are updated using function β off-equilibrium as well.

2. $d_k^*(\underline{p}, \overline{p}) = \hat{d}(\underline{p}, \overline{p}, \mu_k^*, \tau_{UD,k}^*)$ *for* k *in* $\{1, 2, \ldots, n\}$.

   Consumer C_k's equilibrium decision to visit the expert or not follows from the discussion above and is determined using her equilibrium belief μ_k^* and the expert's equilibrium treatment strategy $\tau_{UD,k}^*$. Note that these two elements matter only under equal markups (as explained above) and that consumer C_k's decision is based on the equilibrium treatment strategy even off-equilibrium: after a deviation by the expert from his equilibrium treatment strategy, which is revealed by feedback $(\underline{t}, 0)$ while $\tau_{UD,k-1}^* = \overline{t}$, consumers C_k to C_n believe that he goes back to his equilibrium treatment strategy τ_{UD}^*.

3. $\tau_{UD,n}^* = t^e(\emptyset)$.

   Given that consumer C_n is the last one, the expert is indifferent between treatments $\underline{t}$ and $\overline{t}$ since the outcome has no impact on his payoff which implies that he chooses the efficient treatment.

4. $\underline{p}^* \leq \underline{p}^M(\lambda, \tau_{UD,1}^*) \leq \max\{\underline{p}^M(\lambda, \underline{t}), \underline{p}^M(\lambda, \overline{t})\}$.

   If $\underline{p}^* > \underline{p}^M(\lambda, \tau_{UD,1}^*)$, consumer C_1 would not visit the expert and neither does any other consumer which gives him a zero payoff. However, this cannot be an equilibrium price since the expert can always guarantee a strictly positive payoff for himself. For instance, if the expert deviates to prices with different markups, he can receive the payoff $\max\{v - \overline{c}, (1-h)v - \underline{c}\}$ which is always strictly positive.

5. *If* $0 < h < \Delta c/v$ *and there exists* k *in* $\{1, \ldots, n-1\}$ *such that* $\tau_{UD,k}^* = \underline{t}$ *then* $\underline{p}^* \leq \underline{p}^M(0, \underline{t})$.

   Let h be in $(0, \Delta c/v)$ and assume that there exists k in $\{1, \ldots, n-1\}$ such that $\tau_{UD,k}^* = \underline{t}$. Let k_1 be the smallest such index k. This means that on the equilibrium path and under uninformative diagnosis, consumer C_{k_1}'s belief μ_{k_1} is strictly positive (as no treatment failure could have been observed on any previous consumer). In order to prove the present claim, we now show that if $\underline{p}^* > \underline{p}^M(0, \underline{t})$ then the expert has an incentive to deviate from $\tau_{UD,k_1}^* = \underline{t}$ to treatment $\overline{t}$. This is a consequence of the two following observations:

   (i) If he chooses treatment $\underline{t}$, he anticipates that it would fail with probability $h > 0$ and produce feedback $(\underline{t}, 0)$ so that consumer C_{k_1+1}'s belief would be $\mu_{k_1+1} = 0$ (see equation 6) which would cause her to not visit the expert since prices are too high for a consumer with this belief regardless of the treatment she anticipates ($\underline{p}^* > \underline{p}^M(0, \underline{t})$ which is strictly larger than $\underline{p}^M(0, \overline{t})$ for $h < \Delta c/v$).

   (ii) If he deviates to treatment $\overline{t}$, he would guarantee that consumer C_{k_1+1}'s belief will be $\mu_{k_1+1} = 1$ (see equation 6). This implies that she would visit the expert since $\underline{p}^M(1, \underline{t}) = \underline{p}^M(1, \overline{t}) = v - h\Delta c > \max\{\underline{p}^M(\lambda, \underline{t}), \underline{p}^M(\lambda, \overline{t})\} \geq \underline{p}^*$.

6. *If* $0 < h < \Delta c/v$ *and* $\underline{p}^* \leq \underline{p}^M(0, \underline{t})$ *then* $\tau^*_{UD,k} = \underline{t}$ *for all* k *in* $\{1, \ldots, n\}$.

   If $0 < h < \Delta c/v$ and $\underline{p}^* \leq \underline{p}^M(0, \underline{t})$ then consumers accept to visit the expert regardless of their beliefs about diagnosis informativeness if they expect to receive the efficient treatment $\underline{t}$ under uninformative diagnosis. Therefore, the expert cannot gain by choosing treatment $\bar{t}$ under uninformative diagnosis. Consequently, he chooses the efficient treatment $\underline{t}$.

7. *If* $0 < h < \Delta c/v$ *and* $\tau^*_{UD,k} = \bar{t}$ *for all* k *in* $\{1, \ldots, n-1\}$ *then* $\underline{p}^* \leq \min\{\underline{p}^M(\tilde{\mu}_{n-1}, \bar{t}), \underline{p}^M(\tilde{\mu}_n, \underline{t})\}$.

   Assume that $0 < h < \Delta c/v$ and $\tau^*_{UD,k} = \bar{t}$ for all k in $\{1, \ldots, n-1\}$. If $\underline{p}^* > \underline{p}^M(\tilde{\mu}_{n-1}, \bar{t})$, let k_1 be the smallest index k in $\{1, \ldots, n-1\}$ such that $\underline{p}^* > \underline{p}^M(\tilde{\mu}_k, \bar{t})$. Since $\underline{p}^* \leq \underline{p}^M(\lambda, \tau^*_{UD,1})$, we necessarily have $k_1 > 1$ and this issue is irrelevant for the case of two consumers ($n = 2$). Given that $\tilde{\mu}_k$ decreases as k increases and $\underline{p}^M(\mu, \bar{t})$ is increasing in μ, we find that on the equilibrium path, under uninformative diagnosis, consumers C_1 to C_{k_1-1} would visit the expert but consumer C_{k_1} would refuse to visit him[21], in which case C_{k_1-1} would be the last consumer that the expert receives. Anticipating this outcome, the expert has an incentive to deviate to treatment $\underline{t}$ with consumer C_{k_1-1} under uninformative diagnosis since it can succeed with probability $(1 - h)$ and generate feedback $(\underline{t}, v)$ in which case consumer C_{k_1}'s belief would be $\mu_{k_1} = 1$ (see equation 7) and she would decide to visit the expert ($\underline{p}^* \leq \underline{p}^M(\lambda, \tau^*_{UD,1}) = \underline{p}^M(\lambda, \bar{t}) < \underline{p}^M(1, \bar{t}) = \underline{p}^M(1, \underline{t})$).

   Thus, if $0 < h < \Delta c/v$ and $\tau^*_{UD,k} = \bar{t}$ for all k in $\{1, \ldots, n-1\}$ then we necessarily have $\underline{p}^* \leq \underline{p}^M(\tilde{\mu}_{n-1}, \bar{t})$ and consumers C_1 to C_{n-1} visit the expert under informative and uninformative diagnosis on equilibrium path. Assume that $\underline{p}^* > \underline{p}^M(\tilde{\mu}_n, \underline{t})$. This implies that under uninformative diagnosis, consumer C_n would not visit the expert. The same argument used previously applies in this case and the expert would profit from a deviation to treatment $\underline{t}$ with consumer C_{n-1}. Therefore $\underline{p}^* \leq \underline{p}^M(\tilde{\mu}_n, \underline{t})$.

8. *If* $0 < h < \Delta c/v$ *and* $\underline{p}^M(0, \underline{t}) < \underline{p}^* \leq \min\{\underline{p}^M(\tilde{\mu}_{n-1}, \bar{t}), \underline{p}^M(\tilde{\mu}_n, \underline{t})\}$ *then* $\tau^*_{UD,k} = \bar{t}$ *for all* k *in* $\{1, \ldots, n-1\}$.

   If $\underline{p}^* > \underline{p}^M(0, \underline{t})$ then there exists no k in $\{1, \ldots, n-1\}$ such that $\tau^*_{UD,k} = \underline{t}$. If, in addition, $\underline{p}^* \leq \min\{\underline{p}^M(\tilde{\mu}_{n-1}, \bar{t}), \underline{p}^M(\tilde{\mu}_n, \underline{t})\}$ then the expert cannot gain by deviating from the treatment strategy such that $\tau^*_{UD,k} = \bar{t}$ for all k in $\{1, \ldots, n-1\}$: such prices guarantee that all consumers visit the expert assuming they anticipate this treatment strategies.

9. *If* $0 < h < \Delta c/v$ *then* $\underline{p}^* \leq \max\{\underline{p}^M(0, \underline{t}), \min\{\underline{p}^M(\tilde{\mu}_{n-1}, \bar{t}), \underline{p}^M(\tilde{\mu}_n, \underline{t})\}\}$.

   If $0 < h < \Delta c/v$ and $\underline{p} > \max\{\underline{p}^M(0, \underline{t}), \min\{\underline{p}^M(\tilde{\mu}_{n-1}, \bar{t}), \underline{p}^M(\tilde{\mu}_n, \underline{t})\}\}$ then for any pure treatment strategy that consumers anticipate, the expert would have an incentive to deviate (same arguments as in proofs of claims 5 and 7).

[21] This would also be the case under informative diagnosis if all consumers preceding C_{k_1} have major problems which occurs with some positive probability.

10. *For each $n \geq 2$, there exists $\eta_n \in (0, \Delta c/v)$ such that*

    - $\underline{p}^M(0, \underline{t}) > \min\{\underline{p}^M(\tilde{\mu}_{n-1}, \bar{t}), \underline{p}^M(\tilde{\mu}_n, \underline{t})\}$ *if* $0 < h < \eta_n$*;*
    - $\underline{p}^M(0, \underline{t}) = \min\{\underline{p}^M(\tilde{\mu}_{n-1}, \bar{t}), \underline{p}^M(\tilde{\mu}_n, \underline{t})\}$ *if* $h = \eta_n$*;*
    - $\underline{p}^M(0, \underline{t}) < \min\{\underline{p}^M(\tilde{\mu}_{n-1}, \bar{t}), \underline{p}^M(\tilde{\mu}_n, \underline{t})\}$ *if* $\eta_n < h < \Delta c/v$*.*

    Since $\underline{p}^M(\mu, \underline{t})$ is increasing in μ and $\tilde{\mu}_n > 0$, we have $\underline{p}^M(\tilde{\mu}_n, \underline{t}) > \underline{p}^M(0, \underline{t})$. Thus, it is sufficient to compare $\underline{p}^M(0, \underline{t})$ and $\underline{p}^M(\tilde{\mu}_{n-1}, \bar{t})$.

    We have $\underline{p}^M(0, \underline{t}) = (1-h)v$ and $\underline{p}^M(\tilde{\mu}_{n-1}, \bar{t}) = (v - \Delta c) + \Delta c(1-h)\tilde{\mu}_{n-1} = (v - \Delta c) + \Delta c(1-h)\frac{\lambda h^{n-2}}{\lambda h^{n-2}+1-\lambda}$. Therefore,

    $$\underline{p}^M(\tilde{\mu}_{n-1}, \bar{t}) - \underline{p}^M(0, \underline{t}) = \frac{(1-\lambda)(hv - \Delta c) + \lambda h^{n-1}(v - \Delta c)}{\lambda h^{n-2} + 1 - \lambda}.$$

    Since the denominator is positive, the comparison depends on the sign of the numerator which is negative for $h = 0$, positive for $h = \Delta c/v$ and strictly increasing in h over $(0, \Delta c/v)$. The result follows from this observation.

11. *If* $0 < h \leq \eta_n$ *then* $\tau^*_{UD,k} = \underline{t}$ *for all* k *in* $\{1, \ldots, n\}$ *and* $\underline{p}^* = \underline{p}^M(0, \underline{t})$. *If* $\eta_n < h < \Delta c/v$ *then* $\tau^*_{UD,k} = \bar{t}$ *for all* k *in* $\{1, \ldots, n-1\}$, $\tau^*_{UD,n} = \underline{t}$ *and* $\underline{p}^* = \min\{\underline{p}^M(\tilde{\mu}_{n-1}, \bar{t}), \underline{p}^M(\tilde{\mu}_n, \underline{t})\}$.

    In each case, prices are such that *(i)* all consumers visit the expert assuming they anticipate the corresponding treatment strategy and the expert follows it and *(ii)* the expert follows the treatment strategy assuming consumers anticipate it.

    These prices are the maximum possible prices in equilibrium (claim 9). The expert would not deviate to $\underline{p} > \max\{\underline{p}^M(0, \underline{t}), \min\{\underline{p}^M(\tilde{\mu}_{n-1}, \bar{t}), \underline{p}^M(\tilde{\mu}_n, \underline{t})\}\}$ since there exist off-equilibrium beliefs that make all consumers decide to not visit the expert: for instance $\mu = 0$ achieves this outcome regardless of the anticipated treatment since $\underline{p}^M(0, \underline{t}) = (1-h)v > \underline{p}^M(0, \bar{t}) = v - \Delta c$ for $h < \Delta c/v$.

    Note that in the statement of this result, we break the tie at $h = \eta_n$ in favor of the efficient treatment (in line with our assumption that the expert chooses the efficient treatment whenever he is indifferent).

12. $\eta_2 = \frac{(1-\lambda)\Delta c}{v - \lambda \Delta c} < \frac{\Delta c}{v}$, $\eta_n < \eta_{n+1} < \frac{\Delta c}{v}$ *for* $n \geq 2$ *and* $\lim_{n \to +\infty} \eta_n = \frac{\Delta c}{v}$.

    η_2 is the value of h such that $\underline{p}^M(\tilde{\mu}_1, \bar{t}) - \underline{p}^M(0, \underline{t}) = 0$ which is $\frac{(1-\lambda)\Delta c}{v - \lambda \Delta c}$. The inequality $\eta_2 < \Delta c/v$ is readily obtained using the fact that $v > \Delta c$.

    For $n \geq 2$, we have

    $$(1-\lambda)(\eta_n v - \Delta c) + \lambda \eta_n^{n-1}(v - \Delta c) = 0$$

    and

    $$(1-\lambda)(\eta_{n+1} v - \Delta c) + \lambda \eta_{n+1}^{n}(v - \Delta c) = 0.$$

Since $0 < \eta_n < 1$, we have $\eta_n^n < \eta_n^{n-1}$ and thus

$$(1-\lambda)(\eta_n v - \Delta c) + \lambda \eta_n^n (v - \Delta c) < (1-\lambda)(\eta_n v - \Delta c) + \lambda \eta_n^{n-1}(v - \Delta c) = 0.$$

Given that $(1-\lambda)(hv - \Delta c) + \lambda h^n (v - \Delta c)$ is increasing in h, η_{n+1} must be greater than η_n.

Finally,

$$(1-\lambda)\left(\left(\frac{\Delta c}{v}\right) v - \Delta c\right) + \lambda \left(\frac{\Delta c}{v}\right)^{n-1} (v - \Delta c) = \lambda \left(\frac{\Delta c}{v}\right)^{n-1} (v - \Delta c)$$

which is positive for all $n \geq 2$ and tends to 0 when $n \to +\infty$. Therefore, $\eta_n < \Delta c/v$ for all $n \geq 2$ and $\lim_{n\to+\infty} \eta_n = \frac{\Delta c}{v}$.

13. *If $\Delta c/v \leq h < 1$ and there exists k in $\{1, \ldots, n-1\}$ such that $\tau^*_{UD,k} = \underline{t}$ then $\underline{p}^* \leq \underline{p}^M(0, \bar{t})$.*

    This proof is analogous to that of claim 5. Let h be in $[\Delta c/v, 1)$ and assume that there exists k in $\{1, \ldots, n-1\}$ such that $\tau^*_{UD,k} = \underline{t}$. Let k_1 be the smallest such index k. This means that on the equilibrium path and under uninformative diagnosis, consumer C_{k_1}'s belief μ_{k_1} is strictly positive (as no treatment failure could have been observed on any previous consumer). In order to prove the present claim, we now show that if $\underline{p}^* > \underline{p}^M(0, \bar{t})$ then the expert has an incentive to deviate from $\tau^*_{UD,k_1} = \underline{t}$ to treatment $\bar{t}$. This is a consequence of the two following observations:

    (i) If he chooses treatment $\underline{t}$, he anticipates that it would fail with probability $h > 0$ and produce feedback $(\underline{t}, 0)$ so that consumer C_{k_1+1}'s belief would be $\mu_{k_1+1} = 0$ (see equation 6) which would cause her to not visit the expert since prices are too high for a consumer with this belief regardless of the treatment she anticipates ($\underline{p}^* > \underline{p}^M(0, \bar{t})$ which is strictly larger than $\underline{p}^M(0, \underline{t})$ for $h > \Delta c/v$).

    (ii) If he deviates to treatment $\bar{t}$, he would guarantee that consumer C_{k_1+1}'s belief will be $\mu_{k_1+1} = 1$ (see equation 6). This implies that she would visit the expert $\underline{p}^M(1, \underline{t}) = \underline{p}^M(1, \bar{t}) = v - h\Delta c > \max\{\underline{p}^M(\lambda, \underline{t}), \underline{p}^M(\lambda, \bar{t})\} \geq \underline{p}^*$.

14. *If $\Delta c/v \leq h < 1$ and $\tau^*_{UD,k} = \bar{t}$ for all k in $\{1, \ldots, n\}$ then $\underline{p}^* \leq \underline{p}^M(\tilde{\mu}_n, \bar{t})$.*

    This proof is similar to that of claim 7. Assume that $\Delta c/v \leq h < 1$ and $\tau^*_{UD,k} = \bar{t}$ for all k in $\{1, \ldots, n\}$. If $\underline{p}^* > \underline{p}^M(\tilde{\mu}_n, \bar{t})$, let k_1 be the smallest index k in $\{1, \ldots, n\}$ such that $\underline{p}^* > \underline{p}^M(\tilde{\mu}_k, \bar{t})$. Since $\underline{p}^* \leq \underline{p}^M(\lambda, \tau^*_{UD,1})$, we necessarily have $k_1 > 1$. Given that $\tilde{\mu}_k$ decreases as k increases and $\underline{p}^M(\mu, \bar{t})$ is increasing in μ, we find that on the equilibrium path, under uninformative diagnosis, consumers C_1 to C_{k_1-1} would visit the expert but consumer C_{k_1} would refuse to visit him, in which case C_{k_1-1} would be the last consumer that the expert receives. Anticipating this outcome, the expert has an incentive to deviate to treatment $\underline{t}$ with consumer C_{k_1-1} under uninformative diagnosis since it can succeed with probability $(1-h)$ and generate feedback $(\underline{t}, v)$ in which case consumer C_{k_1}'s belief would be $\mu_{k_1} = 1$ (see equation 7) and she would decide to visit the expert ($\underline{p}^* \leq \underline{p}^M(\lambda, \tau^*_{UD,1}) = \underline{p}^M(\lambda, \bar{t}) < \underline{p}^M(1, \bar{t}) = \underline{p}^M(1, \underline{t})$).

15. *If* $\Delta c/v \leq h < 1$ *then* $\tau^*_{UD,k} = \bar{t}$ *for all* k *in* $\{1, \ldots, n\}$ *and* $\underline{p}^* = \underline{p}^M(\tilde{\mu}_n, \bar{t})$.

    Since $\tilde{\mu}_n > 0$ and $\underline{p}^M(\mu, \bar{t})$ is increasing in μ, we have $\underline{p}^M(\tilde{\mu}_n, \bar{t}) > \underline{p}^M(0, \bar{t})$.

    If $\underline{p} = \underline{p}^M(\tilde{\mu}_n, \bar{t})$ then *(i)* all consumers visit the expert if they anticipate the efficient strategy $\tau_{UD,k} = \bar{t}$ for all k in $\{1, \ldots, n\}$ and *(ii)* the expert cannot gain by deviating from this treatment strategy.

    $\underline{p}^M(\tilde{\mu}_n, \bar{t})$ is the maximum possible value of $\underline{p}^*$: for any higher $\underline{p}$ and any pure treatment strategy that consumers anticipate, the expert would have an incentive to deviate (same arguments as in proofs of claims 13 and 14).

    The equilibrium must be such that $\tau^*_{UD,k} = \bar{t}$ for all k in $\{1, \ldots, n\}$ and $\underline{p}^* = \underline{p}^M(\tilde{\mu}_n, \bar{t})$. Moreover, the expert would not deviate to a higher price since there exist off-equilibrium beliefs that make all consumers decide to not visit the expert: for instance $\mu = 0$ achieves this outcome regardless of the anticipated treatment since $\underline{p}^M(0, \bar{t}) = v - \Delta c \geq \underline{p}^M(0, \underline{t}) = (1 - h)v$ for $h \geq \Delta c/v$.

■

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