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The information paradox in a monopolist's credence goods market☆

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ABSTRACT

Credence good markets, such as those for car repairs and medical treatments, are generally characterized by an ex-ante and ex-post information asymmetry between the uninformed customers and the informed expert. In this paper, we allow for both uninformed as well as informed customers to exist in a monopolist credence goods market. We analyze the implications of this kind of informational heterogeneity for the expert's pricing decisions, incentives to commit fraud, as well as market efficiency and social welfare under different institutional arrangements. Most importantly, our approach enables us to evaluate endeavours to improve the level of customers' information. Contrary to basic intuition, we find that recent developments and policy measures originally aimed at improving social welfare by increasing the level of information might actually backfire.

1. Introduction

Credence goods markets are an important part of daily life, as they encompass common transactions such as medical treatments, repair works, financial consulting, or taxi rides. Often, these markets are plagued by asymmetric information. The seller (also called "expert") is usually better informed about the customer's need and the quality that is necessary to satisfy it. The asymmetric information usually persists even after consumption and creates incentives for fraudulent behavior. This might lead to large inefficiencies from inappropriate treatments as well as from customers anticipating to be defrauded and leaving the market.[2]

Up to now, the existing theoretical literature has focused on the information asymmetries between sellers and buyers, while abstracting from informational differences that exist across customers. This is not surprising, as information asymme-

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[2] For an overview of recent field and lab experiments on credence goods and the extent of fraudulent behavior, see Kerschbamer and Sutter (2017).

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try is the fundamental source of distortion in credence goods markets. Therefore, basic intuition suggests that an improved level of information will always benefit social welfare. This paper challenges this assumption by allowing for heterogeneity in the level of information among customers. We ultimately provide a more nuanced picture and warn against hidden side-effects of recent developments and policy measures that aim at improving the level of information to enhance social welfare.

Whereas it has always been the case that some buyers have more information than others, recent technological developments, in particular, have reinforced the difference in customers' level of information.[3] In the past few years, it has become increasingly common to conduct online research before trading in markets for expert services. Typical examples include online navigation applications that incorporate real-time traffic situations and provide taxi passengers with an idea of the shortest route and the approximate travel time. Further, the internet provides potential investors with sophisticated tools for creating their own portfolio strategies. It also enables people to get a better understanding of the severity of an electronic or mechanical damage and how to repair it. Online information seeking is particularly common for medical treatments. A survey by Pew Research Center found that more than one in three Americans self-diagnose their symptoms online (Fox and Duggan, 2013). According to Agrawal et al. (2018), curated information sources offer reliable and credential information and second opinions for health diagnoses. However, preliminary evidence suggests that the Web is skewed towards a more educated population and as such contributes to creating inequalities in health information accessibility (Weaver, 2013; Jacobs et al., 2017). This implies that nowadays experts should be more prepared than ever before to face customers with different levels of information. Whereas some customers may be completely uninformed about their need and therefore reliant on the seller's diagnosis expertise, others know exactly which product or service they require.

In our model, we allow for this kind of information heterogeneity by introducing two types of customers in a market with a monopolist expert: the first type of customers has full information about the service required to fulfil their need, the other one remains uninformed. This is a simple, yet straightforward way to capture information differences among buyers and examine the associated influence on the expert's pricing decision, the incentive to commit fraud as well as market efficiency and social welfare. Most importantly, this approach lays the foundation that ultimately enables us to comment on the efficiency of efforts to improve the customers' level of information in markets for credence goods under different institutional settings.

The functioning of credence goods markets has been scrutinized in light of different institutional arrangements that pertain to the expert's liability and the verifiability of the treatment's quality. Against this backdrop, previous literature shows that if the expert can be held liable for insufficient treatments, a monopolist credence goods market will be efficient and fraud-free, irrespective of whether the treatment's quality is verifiable or not (see Dulleck and Kerschbamer, 2006, henceforth DK06). Moreover, according to Hyndman and Ozerturk (2011), a market with liability but without verifiability will also be efficient and fraud-free when there exists both uninformed as well as (noisily) informed customers. Hence, it is reasonable to assume that in cases where the expert can be made liable, improving the customers' level of information will be ineffective.[4] For this reason, we focus our main analysis on the implications of heterogenously informed customers in markets where the expert cannot be held liable, and conduct a differentiated analysis with respect to whether the treatment's quality is verifiable or not.

All in all, our analysis leads to the following novel results and policy implications. We show that the intuition regarding the beneficial effects of an improved level of information crucially depends on the prevailing institutional arrangements and can therefore not be unambiguously confirmed. More specifically, increasing the level of information will predominantly lead to clear-cut welfare gains under the setting of missing verifiability, where these improvements are most costly if not impossible to realize. However, under the setting where the treatment's quality is verifiable and that would therefore basically render an improvement in the level of information most feasible, social welfare may deteriorate in response, or will at best remain unaffected. Hence, we strikingly demonstrate that policy measures aimed at improving customers' level of information to enhance social welfare might actually backfire.

Finally, in an extension, we also verify the intuition that under the remaining institutional arrangements where the expert can be made liable, disseminating information lacks any influence on social welfare, as the market remains efficient and fraud-free. In conjunction with our main results, this also implies that with heterogenously informed customers, the expert's liability can be considered as most decisive for determining market outcomes, whereas the verifiability of the treatment's quality does not prove to be a sufficient condition for market efficiency and is therefore only of secondary importance. This is in contrast to previous literature that argues that a monopolist credence goods market will be efficient and fraud-free if *either* the expert can be held liable for insufficient treatments *or* the treatment's quality is verifiable and hence considers these two institutional factors as equally decisive (see DK06).

The remainder of the paper is structured as follows. The next section gives an overview of the relevant literature. We then introduce our model in Section 3 and derive the equilibrium outcomes under different institutional settings in Section 4. Thereafter, we discuss our findings in Section 5 before we conclude with a short summary and prospects for further research.

[3] For example, there have always been other experts in the same field (see, e.g., Domenighetti et al., 1993) or natives and foreigners in a given country (see, e.g., Balafoutas et al., 2013).

[4] We verify this intuition in an extension in Section 4.3.

2. Related literature

In this paper we contribute to the literature on markets for credence goods with a monopolist seller. The notion of credence goods traces back to Darby and Karni (1973). According to their definition, customers do not know ex-ante which quality of a good or service they actually require for satisfying their need. Ex-post, they are only able to identify whether their need was satisfied, but not whether the expert provided the appropriate quality. Sellers can take advantage of this lack of information and defraud the customer. Three types of fraud are possible, which will also be important for the purpose of our paper: (1) If the expert performs and charges for an expensive treatment even though a cheaper treatment would have been sufficient to satisfy the customer's need, this is called *overtreatment*. (2) If the export only provides a cheap treatment even though the customer's problem would require an expensive one, *undertreatment* occurs. (3) If the customer's problem requires only a cheap treatment, but the expert charges for an expensive treatment while performing only the cheap treatment, we speak of *overcharging*. Whereas the first two types of fraud lead to inefficiencies, the last type merely represents a monetary transfer from the customer to the expert.

In our paper we follow the seminal theoretical work on credence goods, which is provided by Pitchik and Schotter (1987) and Wolinsky (1993). We further build upon DK06. The authors introduce a single model that generalizes the analysis of credence goods markets and identify four key assumptions that explain and unify the findings of preceding contributions. Particularly important for our analysis are the assumptions concerning *verifiability* and *liability*.[5] If the type of treatment is verifiable, the customer knows whether he received the low- or high-quality treatment. Therefore, overcharging may not occur. This assumption is reasonable if no special expertise is necessary to evaluate the treatment's quality. For instance, in the case of metered taxis, a longer route might be taken but the price per kilometer cannot be changed. If the expert is liable for solving the customer's problem, undertreatment is unlikely to occur. This is relevant in situations where the outcome of the treatment is observable and verifiable (Bester and Ouyang, 2018). In the context of the previous example, without any due justification, the taxi driver will not be able to charge money for dropping a customer at any destination other than the one stipulated at the beginning.[6]

In addition to verifiability and liability, we identify the distribution of information among customers as a third important factor that influences efficiency and fraud in a monopolist credence goods market. Further, the crucial finding of DK06 is that given customers are homogeneous and are committed to an expert once she carried out her diagnosis, the monopolist market is non-fraudulent and hence efficient if *either* verifiability *or* liability holds. This is in stark contrast to our results, which suggest that even under the assumption of verifiability the market may be inefficient if the expert is not liable. Hence, different to DK06, our paper highlights the supremacy of an expert's liability, whereas the verifiability of the quality provided is only of secondary importance.

Most importantly, we advance the existing literature on credence goods in that we account for informational heterogeneity among customers. In our model, customers differ with respect to the level of information about the quality required for solving their problem. Only a few authors consider some kind of customer heterogeneity. The focus of almost all of these papers, however, is on very specific dimensions that crucially differ from our approach. DK06, for example, consider a monopolist market where customers vary in their expected costs of an efficient treatment. Depending on the available degrees of price discrimination, inefficient rationing or inefficient treatments may exist. In Fong (2005), customers vary in their willingness to pay and in their cost of treatment, both of which is private information. Experts, on the other hand, know what the efficient treatment would be, but the customer's willingness to pay is unknown to them. The resulting equilibrium is an inefficient one, in which neither customers nor sellers reveal their private information. Hyndman and Ozerturk (2011) build upon the paper of Fong (2005) by introducing heterogeneously informed customers with respect to their true benefit from an expensive treatment. In an extension, the authors also consider the case where some customers receive a noisy signal about the severity of their problem. As such, this paper is closest to our analysis. Yet, their analysis is limited to an institutional setting where the expert can only defraud consumers by engaging in overcharging.

Whereas up to now research on informational heterogeneity remains relatively scarce, there are some scholars who are concerned with the possibility that potential buyers acquire information. In Pesendorfer and Wolinsky (2003), customers may ask and pay several experts for their diagnosis before undergoing a treatment. In combination with flexible prices, a Pareto-optimal equilibrium may not be achieved. Feddersen and Gilligan (2001) introduce a third party, "an activist", who may inform customers about the product's quality and show that activists may help to increase social welfare and achieve an efficient equilibrium. A very recent theoretical as well as experimental contribution on information acquisitions is provided by Agrawal et al. (2018). In their model, the customer can exert effort in acquiring information by either conducting personal research or seeking a second opinion. In contrast to the personal research case, inefficiencies always arise in the second opinion case. All in all, if we assume that customers are marked by different costs of conducting information acquisition, this stream of literature can be regarded as an antecedent with respect to our analysis of heterogeneously informed customers.

[5] The other two assumptions concern the commitment of customers to a specific expert and the homogeneity of customers. Whereas we already assume, although in a different interpretation, heterogeneity among customers, we abstain from analyzing the commitment assumption, as it is mainly interesting for markets with competition.

[6] Whereas most studies assume unlimited liability on part of the expert, Bester and Ouyang (2018) as well as Chen et al. (2018) examine the case with limited liability.

3. Model setup

Similar to Pitchik and Schotter (1987), Wolinsky (1993) and DK06 we consider a situation, where a customer (he) has a problem which is either of major or minor severity. The probability of major severity, $h \in [0, 1]$, is common knowledge.

The customer chooses whether to visit an expert (she) for treatment. His outside option is to receive no treatment. If the expert is consulted, she (but not the customer) learns the type of the problem and carries out a treatment.[7] The expert can then choose between two different kinds of treatments: a major treatment costs the expert c_H and solves both the minor as well as the major problem, whereas the minor treatment costs her c_L, but solves only the minor problem. The expert charges prices p_H and p_L. These are posted prior to the customer's decision to visit. If the customer's problem is treated satisfactorily, he obtains a utility of v. We assume $v > c_H > c_L \geq 0$.

We further assume that there is a probability, $k \in [0, 1]$, that the customer is informed.[8] With probability $1 - k$, the customer is not informed. Customers are therefore heterogeneous if $0 < k < 1$. An informed customer has the necessary expertise to evaluate whether his problem is a minor or a major one. The customer's knowledge can be observed by the expert. This is realistic for two reasons: First, experts in a given field are likely known to one another.[9] Secondly, informed customers are able to credibly disclose their knowledge to an expert by using specialized terminology.[10] As already mentioned in the previous section, three types of fraud are possible: 1) overtreatment, 2) undertreatment, and 3) overcharging. Because $c_H > c_L$, any equilibrium involving over- or undertreatment is inefficient, whereas overcharging simply implies a monetary transfer from the customer to the expert. We henceforth assume that it is only uninformed customers that can be defrauded by the expert. This is because informed customers can be considered as some kind of experts themselves in the sense that they know the type of their problem and can always verify the treatment that they received. This implies that they view the expert as a service provider and explicitly demand and pay for the minor (major) treatment in case they have a minor (major) problem. On the other hand, uninformed customers have to rely on the expert's diagnosis.

The timing of the game is as follows: First, the expert sets prices p_H and p_L. Then, "nature" determines the customer's information and the severity of his problem.[11] In a third step, the customer decides whether to visit the expert. If he chooses not to visit, the game ends, in which case he and the expert receive zero utility. If the customer decides to visit, the expert observes the customer's type and either carries out the stipulated treatment in case the customer is informed, or chooses a treatment for the uninformed customer.[12] She then charges the customer price p_H or p_L and bears costs c_H or c_L. The customer then receives v if his problem is solved and zero otherwise. Both actors are assumed to be risk-neutral. If the customer is indifferent between visiting and not visiting the expert, he decides for the former. If the expert is indifferent between fraud and no fraud, she chooses not to commit fraud.

4. Derivation of results for markets without liability

In the main part of our analysis, we focus our analysis on two institutional arrangements. What is common to both settings is that the expert cannot be held liable for insufficient treatments (denoted by L0). However, we vary whether the treatment's quality is verifiable (V1) or not verifiable (V0). In an extension, we also briefly discuss the two cases, where the expert can be held liable (L1) and the treatment's quality is or is not verifiable. Note that the assumptions concerning the treatment's *liability* and the expert's *verifiability* determines the expert's possibilities to commit fraud. If the expert cannot be made fully liable for insufficient treatments, undertreating uninformed customers is an option. Without verifiability, the expert has an incentive to overcharge the treatments for uninformed customers (as opposed to overtreat) as long as $p_H > p_L$, because $p_H - c_L > p_H - c_H$. If verifiability is assumed, overcharging may not occur.

For each of our two main institutional settings, we first derive the market equilibria and also compare the results of our model to the baseline model of $k = 0$. This approach helps to develop a more nuanced intuition of how the co-existence of informed and uninformed customers influence the expert's incentives. We describe the market equilibria with respect to whether it is non-fraudulent, i.e. whether the expert refrains from undertreatment, overtreatment and overcharging, and with respect to whether it is efficient. In addition to the absence of over- and undertreatment, efficiency also requires that both customer groups choose to participate in the market and visit the expert. Thus, efficiency entails a maximum social

[7] At this point, we abstain from assuming a costly diagnosis because this is mainly relevant for a non-monopolistic market. An exception is Bester and Dahm (2017), who consider a monopolist framework with costly diagnosis where the outcome of a treatment can only be subjectively evaluated by the customer.

[8] This is a simple yet straightforward way of modeling the existence of informed customers that captures the key aspects while still ensuring analytical tractability.

[9] See, for example, Domenighetti et al. (1993) who analyze medical and surgical services among consumers in a Swiss canton. They find that doctors and their families had significantly less surgeries than the population average.

[10] As local versus foreign dialects also fit in this category, the findings of Balafoutas et al. (2013) support this assumption by demonstrating that taxi drivers react differently depending on whether they face a native or a foreigner.

[11] We assume this order of seller's price setting before nature's determination, as it allows us to work with proper subgames. The model's results are not affected by that decision. Also, as the institutional environment of most credence goods markets prohibits using of a menu of contracts, we abstract from the possibility of screening.

[12] Note that this is akin to the commitment assumption of DK06 as at this point uninformed customers have to accept whatever treatment the expert chooses for him. We discuss the case where the customer is not committed to accepting the treatment recommendation in Section 6.

welfare of $SW_{max} = v - c_L - h(c_H - c_L)$. Note that even if the expert overcharges the uninformed customer and therefore the market is fraudulent, it may still be efficient as overcharging only constitutes a monetary transfer from the customer to the expert. After explaining the basic intuition behind the market equilibria, we focus on how improving the customers' level of information affects social welfare. Note that for this purpose, the probability k that a customer is informed can also be considered as the share of informed customers in the market. At the same time, a general improvement in the level of customers' information can be illustrated by an increase in k. Comparative statics of social welfare with respect to k then allows us to draw conclusions with respect to the efficiency of information campaigns in credence goods markets.

4.1. Markets without Liability but with Verifiability (L0,V1)

Let us first consider a market where the expert cannot be held liable for insufficient treatment but the treatment is verifiable. Therefore, uninformed customers do not face the risk of being overcharged but may fear over- or undertreatment.

To begin with, assume for a moment that all customers are uninformed, $k = 0$. As shown by DK06, the only equilibrium in the market satisfies the following conditions with regard to the expert's pricing decision:

$$hp_H + (1-h)p_L = v \tag{1}$$

and

$$p_H - c_H = p_L - c_L. \tag{2}$$

With the latter condition, the monopolist sets equal mark-ups and can therefore credibly signal not to under- or overtreat the customer but to sufficiently and efficiently solve the problem. Nevertheless, the first condition implies that she sets prices such as to extract all of the customer's expected rent. All in all, $p_L = v - h(c_H - c_L)$, $p_H = v + (1-h)(c_H - c_L)$ and the seller's expected profit will be $\Pi_{max} = v - c_L - h(c_H - c_L)$. The market is non-fraudulent and efficient as the optimal welfare $SW_{max} = \Pi_{max}$ is achieved. Note, that $c_H > c_L$ together with condition (2) implies $p_H > p_L$. Hence, by condition (1) $p_H > v > p_L$.

Now assume that some share of uninformed customers becomes informed. There are now essentially three pricing strategies that the expert may choose. The first strategy (strategy a) is to stick to her prices such that conditions (1) and (2) are fulfilled. In this case, however, an informed customer will refrain from visiting the expert if his problem is a major one, as $p_H > v$. The seller's expected profits decreases to $\Pi_a = (1-hk)(v - c_L - h(c_H - c_L))$.

The higher the share of informed customers is, the more profits the expert continues to lose by adhering to strategy a. As uninformed customers already receive their reservation utility, the only option to compensate for the losses is to keep informed customers with a major problem from leaving the market. She can do that by decreasing p_H to $p'_H = v$. However, because $p'_H - c_H < p_L - c_L$ she would then have an incentive to undertreat uninformed customers. Anticipating this incentive, the uninformed customers would in turn leave the market. The expert now has two options, which leads to two additional strategies: The second strategy (strategy b) is to counteract the uninformed customer's incentive to leave the market by reducing p_L to $p'_L = v - (c_H - c_L)$, resulting in total profits of $\Pi_b = v - c_H$. This leads to higher profits than sticking to her prices if $k > k_{ab} = \frac{(1-h)(c_H - c_L)}{h(v - c_L - h(c_H - c_L))}$. For the third strategy (strategy c), the expert accepts the fact that she will only treat informed customers. In this case, she will fully abolish the undertreatment constraint and maximizes her profits on informed customers by increasing p_L to $p'_L = p'_H = v$. If the share of informed customers is sufficiently high, i.e. $k > k_{ac} = \frac{1}{1+h}$, the resulting profit of $\Pi_c = k(v - c_L - h(c_H - c_L))$ is higher than the profit from strategy a. Lastly, there exists a threshold $k_{bc} = \frac{v - c_H}{v - c_L - h(c_H - c_L)}$, such that for any $k < k_{bc}$ the expert's profit from strategy b is higher than from strategy c and lower otherwise (see also Fig. 1).

Importantly, it is only strategy b that leads to an efficient market, as the expert serves both customer groups in a non-fraudulent way. Whereas the other two strategies a and c are also non-fraudulent, they are inefficient as under strategy a informed customers with a major problem and under strategy c uninformed customers leave the market.

Lemma 1. *There exists a threshold $k' > 0$, such that for a sufficiently low share of informed customers, $k < k'$, the market is non-fraudulent but inefficient as informed customers with a major treatment will leave the market.*

As explained above, strategy a will dominate the other two strategies if $k < min\{k_{ab}, k_{ac}\}$. Note that there exists a threshold $h^* = \frac{c_H - c_L}{v - c_L}$, such that $k_{ab} = k_{ac}$. For any $h < h^*$, $k_{ab} > k_{ac}$. If $h > h^*$, $k_{ab} < k_{ac}$. We can now define a function $k' = \min\{k_{ab}, k_{ac}\} > 0$, such that for $h \geq h^*$, $k' = k_{ab}$ and $k' = k_{ac}$ otherwise. It then follows that strategy a will be sustained in equilibrium if $k < k'$(see also the light-gray area in Fig. 1).

The intuition for the result of Lemma 1 is straightforward. If the share of informed customers is sufficiently low, $k < k'$, the expert does not incur major losses by setting prices in a way that focus on extracting the rents of uninformed customers at the cost of inducing informed customers with major problems to leave the market.

The result in Lemma 1 leads to several implications. Whereas uninformed customers remain unaffected when compared to the case where $k = 0$ and obtain their outside utility of zero, the expected surplus of informed customers increases to $(1-h)(v - p_L) = h(1-h)(c_H - c_L) > 0$ and the seller's expected profits Π_a decreases to $(1-hk)(v - c_L - h(c_H - c_L))$.[13] As the

[13] These results are obtained by using the respective prices under strategy a, $p_L = v - h(c_H - c_L)$, $p_H = v + (1-h)(c_H - c_L)$.

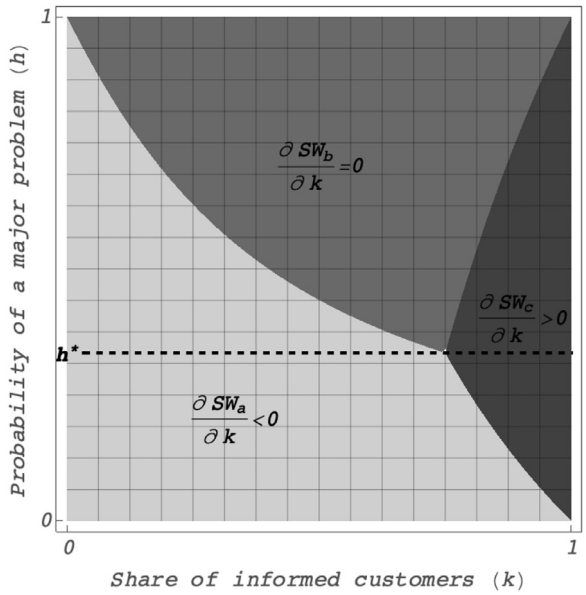

Fig. 1. Parameter regions where pricing strategy *a* (light-gray), *b* (gray) or *c* (dark-gray) will prevail in equilibrium under L0 and V1 ($v = 1$, $c_L = 0.25$, $c_H = 0.5$).

seller's loss exceeds the informed customers' expected benefit, social welfare, now equal to $SW_a = (1 - kh)v - (1 - k)hc_H - (1 - h)c_L$, is lost relative to the case where $k = 0$. Also, $\partial SW_a/\partial k < 0$, as a higher level of k implies a higher probability that the potential buyer will be an informed customer with a major problem and will therefore not participate in the market.

Lemma 2. *There exists a threshold $k'' < 1$, such that for a sufficiently high share of informed customers, $k > k''$, the market is non-fraudulent but inefficient. Uninformed customers leave the market because they fear the potential fraud of undertreatment.*

Strategy *c* will dominate the other two strategies if $k \geq \max\{k_{ac}, k_{bc}\}$. As before, if $h = h^*$, it holds that $k_{ac} = k_{bc}$. For any $h < h^*$, $k_{ac} > k_{bc}$ and vice versa. We can again define a function $k'' = \max\{k_{ac}, k_{bc}\} > 0$, such that for $h \geq h^*$, $k'' = k_{bc}$ and $k'' = k_{ac}$ otherwise. It then follows that for $k > k''$, strategy *c* will be sustained in equilibrium (see also the dark-gray area in Fig. 1).

In order to develop an intuition for Lemma 2, assume for a moment that all customers in the market are informed, so $k = 1$. In this case, the expert can easily extract the whole rent by setting $p_H = p_L = v$ (strategy *c*). If there exist at least some uninformed customers in the market, they rightly fear that their major problems will be undertreated, which is why their willingness to pay declines to $(1 - h)v$. Hence, prices exceed their willingness to pay and they choose to not visit the expert. This, in turn renders the market inefficient but fraud-free.

If the share of informed customers *k* decreases further, the expert continues to lose profits by sticking to strategy *c* as she drives more and more uninformed customers out of the market. As shown before, either adjusting prices to fulfil conditions (1) and (2) and tolerating informed customers with a major problem to leave (strategy *a*) or treating both customer groups with prices of $p_H = v$ and $p_L = v - (c_H - c_L)$ (strategy *b*) will then become more profitable.

Under strategy *c*, the customer surplus remains unaffected when compared to the case where $k = 0$ as both informed as well as uninformed customers receive their outside utility of zero. The seller's expected profits are $\Pi_c = k(v - c_L - h(c_H - c_L))$, which consequently also equals social welfare. As the market is inefficient, social welfare is lower than under the case of $k = 0$. It is now also obvious that social welfare increases in *k*, i.e. $\partial SW_c/\partial k > 0$, as a higher share of informed customers implies that more customers will participate in the market.

Lemma 3. *There exists an efficient and non-fraudulent market if the share of informed customers is neither too high nor too low, $k \in [k', k'']$, and if the probability of a major problem is sufficiently high, $h \geq h^*$.*

The intuition for Lemma 3 is as follows. Note that in this equilibrium, both customer groups obtain positive rents. If the share of informed customers increases, it will eventually pay off to abandon uninformed customers and focus solely on extracting the rents of informed customers (strategy *c*). As shown before, this is beneficial for $k > k_{bc}$. Similarly, if the share of informed customers is sufficiently low, the loss in profits from uninformed customers with a major problem leaving the market under strategy *a* will be compensated by the possibility to extract the rents of uninformed customers. This is true for $k < k_{ab}$. Also, if the probability of a major problem *h* is sufficiently low, $h < h^*$, serving both customer groups will never be the optimal strategy. Intuitively, either *h* is sufficiently low such that the losses associated with strategy *a* will be limited, or *k* is sufficiently high such that it pays off to focus on informed customers only. As mentioned before, if $h \geq h^*$,

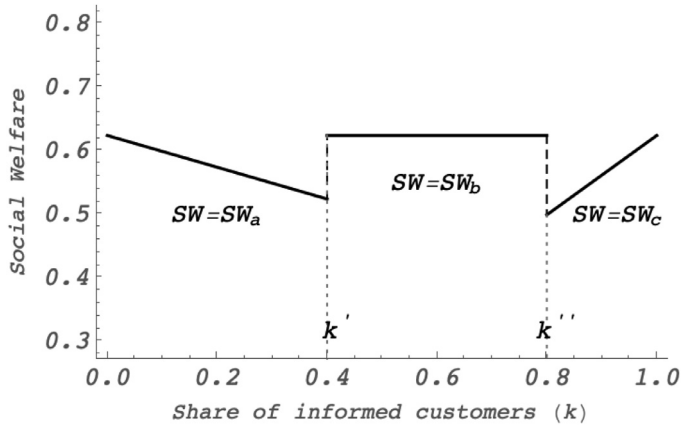

Fig. 2. Social welfare under pricing strategies a, b and c under L0 and V1 ($v = 1$, $c_L = 0.25$, $c_H = 0.5$, $h = 0.5$).

$k' = k_{ab}$ and $k'' = k_{bc}$. All in all, this means that pricing strategy b will be sustained in equilibrium if the share of informed customers is in an intermediate range, $k \in [k', k'']$, and the probability of a major problem is sufficiently high, $h \geq h^*$ (see also the gray area in Fig. 1). In this equilibrium, both customer groups obtain a positive expected utility of $(1-h)(c_H - c_L)$. Also, the expert's profit of Π_b is independent of h and k and social welfare always sums up to SW_{max}. As both customer groups are treated equally, a higher share of informed customers leaves social welfare unaffected, i.e. $\partial SW_b/\partial k = 0$.

We can now summarize our previous discussion in the following corollary:

Corollary 1. *If the expert cannot be held liable for insufficient treatments but the treatment's quality is verifiable, a market with heterogeneously informed customers, $k \in (0,1)$, is only efficient if the probability of severe problems is sufficiently high with $h \geq h^*$ and the share of informed customers is in an intermediate range, $k \in [k', k'']$.*

Otherwise, the market is inefficient and social welfare is lower than in a market with uninformed customers only, $k = 0$.

Corollary 1 directly follows from Lemmas 1–3. With heterogeneously informed customers, $0 < k < 1$, and for a sufficiently low probability of a major problem, $0 < h < h^*$, the two existing equilibria are all inefficient as some customer always decide to leave the non-fraudulent market (see Lemmas 1 and 2).[14] Assume now that $h > h^*$ and take $k = 0$ as the starting point. If some of the previously uninformed customers now become informed, Lemma 1 shows that the market will be inefficient as long as $k < k'$. This is because informed customers with a major problem will decline the expert's visit. If the share of informed customers increases further, efficiency can be re-established given that $k' \leq k \leq k''$ (see Lemma 3). Both customer groups will be served in a non-fraudulent way. If the level of information in the market improves further, $k > k''$, social welfare is not maximized once again, as now uninformed customers fear to be undertreated and leave the market. All in all, if $h > h^*$, the market with heterogeneously informed customers can both be efficient or inefficient. Remember that in a market where all customers are uninformed, $k = 0$, social welfare is always at its maximum if the treatment's quality is verifiable. All in all, Corollary 1 therefore shows that this result established by DK06 is no longer valid if the share of informed customers is sufficiently high or sufficiently low.

Our discussion with regard to Lemmas 1–3 now leads to our first main proposition (see also Fig. 2).

Proposition 1. *If the expert cannot be held liable for insufficient treatments but the treatment's quality is verifiable, we obtain the following:*

$$\frac{\partial SW}{\partial k} \begin{cases} < 0 & \text{for } 0 < k < k', \\ = 0 & \text{for } k' \leq k \leq k'' \text{ and } h \geq h^*, \\ > 0 & \text{for } k'' < k < 1, \end{cases}$$

$$\text{and} \quad SW(k \in [k', k'']) \geq SW(k \notin [k', k'']).$$

Hence, improving the level of information is not always welfare-enhancing and might even result in welfare losses.

As the share of informed customers can also be interpreted as the level of information in the market, our previous analyses demonstrate that the intuition regarding the beneficial welfare effects of improving the level of information predominantly holds if k is already sufficiently high. This is because then the expert follows the strategy of abandoning uninformed customers and focusing on informed customers only. In most other cases, social welfare is either unaffected by a marginal increase in k as social welfare is already at its maximum or even declines as informed customers with major problems don't

[14] For the sake of brevity, we would like to only briefly mention that for the special case of $c_L = 0$, $h < h^*$ and $k = k_{ac}$, there also exists a weakly-dominated, inefficient equilibrium with undertreatment, where all customers enter the market. Details will be provided from the authors upon request.

participate in the market.[15] Note that if we drop the implicit assumption that improving the level of information is costless, an even more drastic picture emerges.

4.2. Markets with neither Liability nor Verifiability (L0,V0)

In a market where the treatment's quality is not verifiable and the expert cannot be held liable, the monopolist has the possibility to overcharge as well as to undertreat uninformed customers. Whereas the expert can generally also overtreat the uninformed customer, this strategy is always dominated by overcharging. In turn, uninformed customers legitimately fear to be defrauded. Even if the expert sets her prices such as to fulfil condition $p_H - c_H = p_L - c_L$, she always has an incentive to offer the minor treatment at the price of the major one, irrespective of the problem's severity she observes.

Given this behavior, it is sufficient to consider the case in which the monopolist sets only one price in equilibrium, $p_H = p_L$. In the case with uninformed customers only, $k = 0$, their expected utility of visiting the expert is $(1-h)v - p_L$. Hence, the expert will set $p_H = p_L = (1-h)v$ in order to maximize profits. Note that if $(1-h)v < c_L$, her profit will be negative. Hence, if $h > h^0$, with $h^0 = \frac{v-c_L}{v}$, a market with only uninformed customers will necessarily break down and social welfare is at its minimum. In all other cases, the expert extracts the uninformed customers' surplus and obtains profits of $(1-h)v - c_L$. As either the market breaks down or uninformed customers will be undertreated, both equilibria are inefficient.

Let us now turn to a market with heterogeneously informed customers, $0 < k < 1$. Similar to the last section, the expert faces the decision between two options: either she chooses a price that is sufficiently low such that uninformed costumers still participate in the market or she chooses to serve informed costumers only, in which case the price she charges will be higher than in the first case.

In the first case, an uninformed costumer is willing to visit the expert if his expected value of a minor problem being treated is higher than the charged price. Hence, if the expert decides to serve both customer groups, she optimally sets $p_H = p_L = (1-h)v$ and always undertreats uninformed customers with a major problem. We will refer to this strategy as strategy e. Her profit in this scenario is $\Pi_e = (1-h)v - khc_H - (1-kh)c_L$ and the utility of informed consumers is hv, which is strictly greater than the uninformed customer's utility of 0. Note that with this pricing strategy, the expert's profit decreases in k.

In the second case, the expert focuses on informed customers only. The maximal price she can charge is $p_H = p_L = v$, which is equivalent to strategy c introduced in the previous subsection. Hence, the resulting profit is $\Pi_c = k(v - hc_H - (1-h)c_L)$. Although uninformed customers leave the market and informed customers visit the expert, both customer groups obtain their reservation utility of 0. Note that in this case, the market is actually fraud-free.

Lemma 4. *If the expert cannot be held liable for insufficient treatments and the treatment's quality is not verifiable, a market with heterogeneously informed customers always exists but is always inefficient. For a sufficiently high share of informed customers, $k \geq k_{ce}$, or a sufficiently high probability of a major problem, $h \geq h^0$, the market is also non-fraudulent as uninformed customers leave the market. Otherwise, uninformed customers will always be undertreated.*

According to Lemma 4, there exists a critical value $k_{ce} = \frac{(1-h)v-c_L}{v-c_L}$ such that for $k < k_{ce}$ and $h < h^0$ the expert is better off with the first strategy e of serving both customer groups. Otherwise, for $k \geq k_{ce}$ or $h \geq h^0$, the expert's profit is higher under pricing strategy c that pushes uninformed customers out of the market (see also Fig. 3).

The intuition is similar to the previous subsection. Obviously, the higher the share of informed customers in the market, the more profitable is the strategy that focuses on informed customers only (strategy c) and vice versa. Additionally, if the probability of a major problem, h, exceeds a certain threshold, strategy c will always dominate as it becomes more costly in terms of forfeited profit to keep uninformed customers from leaving the market. To sum up, under this institutional setting, the monopolist expert cannot credibly signal to refrain from defrauding uninformed customers. Hence, inefficiencies necessarily arise either because uninformed customers will be undertreated or because they leave the market.

Corollary 2. *If the expert cannot be held liable for insufficient treatments and the treatment's quality is not verifiable, social welfare in a market with heterogeneously informed customers, $k \in (0,1)$, is generally higher than in a market with uninformed customers only, $k = 0$.*

Only if the share of informed customers is neither too low nor too high, i.e. $k_{ce} < k < k'_{ce}$, and if the probability of a major problem is sufficiently low, $h < h^0$, social welfare is lower under $k \in (0,1]$ than under $k = 0$.

The intuition for Corollary 2 is as follows. Note that if $h > h^0$, a market with only uninformed customers $k = 0$ will necessarily break down. In the face of heterogeneously informed customers, $0 < k < 1$, the expert is able to ensure that at least informed customers will always be treated. In this case, the existence of informational heterogeneity among customers will save the market from breaking down and hence improve efficiency relative to the benchmark case of $k = 0$. Given that $h < h^0$, the existence of informed customers also leads to higher social welfare if $k \notin (k_{ce}, k'_{ce})$ and to welfare losses otherwise. If $k < k_{ce}$, the expert will serve both customer groups and has to treat informed customers efficiently, which is the reason for the positive welfare effects of the existence of informational heterogeneity among customers. If $k \in (k_{ce}, k'_{ce})$,

[15] The only exception occurs if the level of informed customers is exactly at $k' - \epsilon$, where ϵ is an infinitely small but positive number. Then, marginally improving the level of k also improves social welfare.

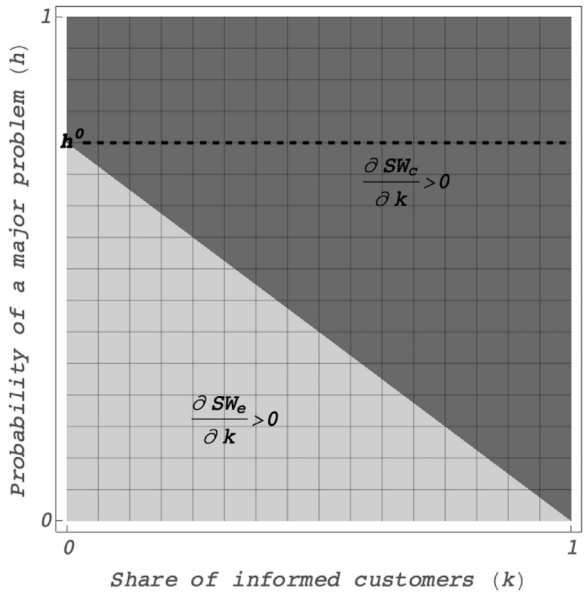

Fig. 3. Parameter regions where pricing strategy e (light-gray), or c (dark-gray) will prevail in equilibrium under L0 and V0 ($v = 1$, $c_L = 0.25$, $c_H = 0.75$).

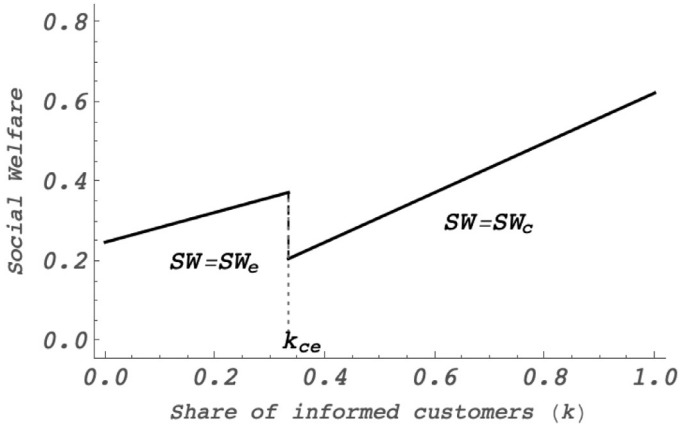

Fig. 4. Social welfare under pricing strategies c and e under L0 and V0 ($v = 1$, $c_L = 0.25$, $c_H = 0.5$, $h = 0.5$).

the expert finds it beneficial to switch from strategy e to strategy c. She abandons a relatively large share of uninformed customer, which harms social welfare. Finally, if $k > k'_{ce}$, a large share of customers receives an efficient treatment, which ultimately outweighs the loss of uninformed customers and again improves social welfare relative to the case where $k = 0$.

The above discussion now allows us to formulate our next major proposition with regard to the welfare effects of improving the level of information in a credence goods market (see also Fig. 4).

Proposition 2. *If the expert cannot be held liable for insufficient treatments and the treatment's quality is not verifiable, we obtain the following:*

- *For* $h \geq h^0$, *it holds that* $\frac{\partial SW}{\partial k} > 0$ for all $k \in (0, 1)$.
- *For* $h < h^0$, *it holds that* $\frac{\partial SW}{\partial k} > 0$ for all $k \in (0, k_{ce})$ *and* $k \in [k_{ce}, 1)$ *and* $SW(k \in (0, k_{ce}) \geq SW(k = k_{ce})$.

Hence, marginally improving the level of information generally proves to be welfare-enhancing.

Note that whenever $h \geq h^0$, social welfare unambiguously increases if the level of information, k, is improved as $k_{ce} < 0$ and the expert always follows pricing strategy c. If $h < h^0$, marginal improvements in the level of information predominantly improve social welfare as well, with the only exception being at $k = k_{ce} - \epsilon$, where ϵ is an infinitely small but positive number. At this point, social welfare experiences a sudden drop as the expert has an incentive to change her pricing strategy from strategy e to strategy c.

Table 1
Summary regarding market efficiency and existence of fraud given the baseline model of DK06 with uninformed customers only ($k = 0$) and our model with information heterogeneity among customers ($k \in (0, 1)$) for the two institutional settings L0,V1 and L0,V0.

		V1	V0
L0	$k = 0$	efficient + fraud-free	inefficient + fraudulent/fraud-free
	$k \in (0,1]$	efficiency =/↓ fraud =	efficiency ↑/↓ fraud =/↓

4.3. Markets with Liability ((L1,V0), (L1,V1))

For the sake of completeness, we now briefly discuss the implications of improving the level of customers' information for the two remaining markets where the expert can be held liable for insufficient treatments and where the treatment's quality is either verifiable or not verifiable.

Proposition 3. *If the expert can be held liable for insufficient treatments, we obtain the following:*

$$\frac{\partial SW}{\partial k} = 0 \qquad \text{for } 0 < k < 1.$$

Hence, irrespective of whether the treatment's quality is verifiable or not, improving the level of information does not affect social welfare.

Proposition 3 directly follows from the fact that, as in DK06 with $k = 0$, the market under both institutional arrangements is always efficient and fraud-free. Social welfare is then equal to $SW = SW_{max} = v - c_L - h(c_H - c_L)$, which is independent of k.

The market with liability but without verifiability is akin to Hyndman and Ozerturk (2011). In this case, the expert will always have an incentive to overcharge and hence to always charge p_H to uninformed customers, but will refrain from over- or undertreatment. As all customers know that their problem will definitely be solved, their overall willingness to pay is v and the expert sets $p_H = v$. Given that $p_L < p_H$, the expert could always boost profits on informed customers by increasing p_L to p_H. In equilibrium, $p_H = p_L = v$ and the expert treats both customer groups. The resulting equilibrium is efficient and fraud-free.

For the market with liability and verifiability, note that neither overcharging nor undertreating uninformed customers is feasible. Again, customers know that they will always be satisfied, so their willingness to pay is v. The only possibility to defraud uninformed customers is to resort to overtreatment, which is why the expert will set $p_H = v$. Similar to before, given that $p_L < p_H$, the expert can improve on informed customers by increasing p_L to $p_H = v$, thereby extracting the market's entire surplus, $\Pi_{max} = SW_{max}$ and rendering overtreatment unprofitable. Therefore, the market is always efficient and fraud-free.

5. Discussion and implications of the level of customers' information

First of all, Table 1 provides an overview of our main discussion in Sections 4.1 and 4.2 with respect to the comparison of the baseline model with uninformed customers only, $k = 0$, and our full-fledged model with the co-existence of informed and uninformed customers, $k \in (0, 1)$.

Most importantly, the insights we obtained with respect to the implications of improving customers' level of information on social welfare now culminate in Proposition 4, which presents the major result of our paper.

Proposition 4. *The welfare effects of marginally improving customers' level of information crucially depend on the institutional arrangements. In particular, we obtain the following results.*

- $\frac{\partial SW}{\partial k} > 0$ *if the expert cannot be held liable and one of the following criteria are satisfied:*
  - *the treatment's quality is verifiable and the level of information in the market is already sufficiently high, i.e.* $k > k''$,
  - *the treatment's quality is not verifiable.*
- $\frac{\partial SW}{\partial k} < 0$ *if the expert cannot be held liable but the treatment's quality is verifiable and the level of information in the market is still relatively low, i.e.* $k < k'$.
- $\frac{\partial SW}{\partial k} = 0$ *if one of the following criteria are satisfied:*
  - *the expert can be held liable,*
  - *the expert cannot be held liable but the treatment's quality is verifiable, the level of information in the market is in an intermediate range, i.e.* $k' \leq k \leq k''$ *and the probability of a major treatment is sufficiently high, i.e.* $h \geq h^*$.

Basic intuition suggests that as information heterogeneity are usually the fundamental source of distortions, an improved level of information will be beneficial for social welfare. However, our analysis reveals that the consequences of informed customers significantly depend on the prevalent market institutions. We demonstrate that a necessary condition for positive welfare effects of information improvements is that the expert cannot be held liable for insufficient treatments. More specifically, improving the level of information is most promising if the treatment's quality is not verifiable. Under verifiable treatments, social welfare might even deteriorate with an improved level of information. Finally, if the expert can be held liable, improving the level of information lacks any influence on profits and social welfare.

Our results now also allow us to discuss the implications of endeavors to improve customers' level of information for social welfare. First, if the expert is not liable and her treatment is not verifiable, an improvement in the level of customers' information will predominantly lead to an increase in market efficiency. The latter institutional setting is particularly relevant for repair works and certain medical treatments. As DK06 discuss, it might be difficult to judge whether the expert replaced or only fixed a broken part, for example, if this part can only be revealed by using special equipment. Also, an insufficient repair might solve the problem for some time, but eventually the product will stop working again. In this case, the break-down cannot be unambiguously traced back to the expert's behavior, which is why liability is difficult to enforce. Similarly, with regard to complex medical treatments, it is reasonable to assume that most patients lack the necessary education to evaluate the treatment's quality. Also, in many situations they are not physically able to do so. At the same time, it might be nearly impossible for a court to verify the success of a medical treatment, as for many diseases a full recovery is unlikely, the effectiveness of a treatment is affected by significant noise and symptoms like pain are impossible to objectively verify (DK06).

Importantly, if the expert is not liable but her treatments are verifiable, disseminating information will be most promising for social welfare if the customers' existing knowledge base is already relatively high. Otherwise, it is at best ineffective and may even be harmful. Consider, for example, a patient suffering from knee pain, which might simply be the result of physical overload, in which case rest will be sufficient, or might be due to out-of-position joints that cause ligaments and tendons to chafe, in which case surgery might be necessary. Obviously, the type of the treatment is observable by the patient. Still, in light of the aforementioned reasons, it remains doubtful that the expert can be made liable for suggesting rest rather than immediately starting a comprehensive treatment.

Our paper hence demonstrates that improving customers' level of information, for example through informational webpages for self-diagnostics or patient discussion forums, may be a desirable and worthwhile development for improving social welfare particularly if treatments are of a high complexity such that they are difficult to verify and experts are unlikely to be held liable. However, it is exactly under these situations that providing information to customers will encounter its limits. Hence, efforts to improve the level of information – such as the project of the American Accreditation HealthCare Commission who work with health providers, researchers, consumers organizations and search engines including Google, Yahoo! and AOL, on improving results for consumer health searches online (Weaver, 2013) – might at best prove to leave social welfare unaffected.

Finally, we want to briefly mention one further implication of our results. The traditional model of DK06 with $k = 0$ predicts that the market will always be efficient if either the expert's treatment is verifiable or she can be held liable. Hence, this finding suggest that the expert's liability and the treatment's verifiability are of equal importance for securing efficiency. This is in stark contrast to our results. As opposed to DK06, our paper highlights the supremacy of an institutional arrangement where the expert can be held liable, whereas the verifiability of the quality provided is only of secondary importance.[16]

6. Summary and further research

In this paper, we acknowledge the existence of informational heterogeneity among customers in a credence goods market and examine how this affects an expert's pricing decision, incentives to commit fraud as well as market efficiency. Most importantly, our model allows us to evaluate the effects of endeavors to improve customers' level of information on social welfare. Contrary to intuition, more information does not always result in welfare gains. If the expert can be held liable for an insufficient treatment, we show that efforts to disseminate information among a broader customer base are actually redundant as they leave social welfare unaffected. If, on the other hand, the expert cannot be held liable, it depends on the assumption regarding the treatment's verifiability whether an improved level of information can actually improve social welfare. More specifically, if the expert is not liable and her treatment is not verifiable, an improvement in the level of customers' information will predominantly lead to an increase in market efficiency. Importantly, if the expert is not liable but her treatments are verifiable, disseminating information will be most promising for social welfare if the customers' existing knowledge base is already relatively high. Otherwise, it is at best ineffective and may even be harmful. Hence, we warn against unintended negative side effects of policy measures aimed at improving customers' level of information to improve social welfare as they might actually backfire.

Finally, previous literature shows that a monopolist credence goods market will be efficient and fraud-free if *either* the expert can be held liable for insufficient treatments *or* the treatment's quality is verifiable. It therefore considers these two

[16] This finding is also in line with the experimental study of Dulleck et al. (2011). Whereas they demonstrate the central importance of the liability assumption, they do not find any noteworthy effects of the assumption regarding the treatment's verifiability.

institutional factors as being equally decisive for ensuring market efficiency (see DK06). In contrast to this, we find that the verifiability of the treatment's quality does not prove to be a sufficient condition. Overall, our paper suggests that the expert's liability is superior for determining market outcomes and efficiency, whereas the verifiability of the credence good's quality is only of secondary importance.

Our paper allows for various potentially fruitful extensions and avenues for further research. In the major part of the paper, we assume that customers are committed to follow the expert's treatment recommendation once they chose to visit the expert. Further, the expert can observe whether the customer is informed or uninformed. First, our preliminary analysis shows that relaxing the commitment assumption does not significantly change our results. Instead of an inefficient equilibrium where informed customers with a major problem leave the market, we now obtain an inefficient equilibrium where uninformed customers will always be undertreated. Overall, this leads to a more efficient market, as uninformed customers can now also discipline the expert by rejecting the treatment recommendation once she tries to charge $p_H > v$ and the efficient and non-fraudulent strategy b can now more often be sustained in equilibrium. Furthermore, when we additionally assume that the customer's level of information is private knowledge, two cases can be differentiated. First, if customers are able to voluntarily disclose their type and disclosure is verifiable, our previous analysis makes it clear that informed customers will always choose to disclose their type as they are always better off and results are hence identical. Second, if the disclosure of one's type is not verifiable, our preliminary analysis shows that the expert will always find it profitable to refrain from under- or overtreatment and is able to extract customers' whole surplus by setting $p_H = p_L = v$. Hence, the resulting equilibrium is both efficient and fraud-free and the level of customers' information k does not influence social welfare. Remaining ignorant about the customers' level of information, however, will serve as a costless commitment device to always refrain from undertreatment. Interestingly and contrary to basic intuition, this implies that dissolving the information asymmetry between the expert and the customers with respect to k might actually lead to a reduction in social welfare.[17] Also, our model assumes that the share of informed customers is exogenously given. This of course neglects the preceding question of why some customers choose to acquire information and others do not. Obviously, for obtaining a market where only a share of customers is informed and the other is uninformed, the costs of information acquisition have to differ. In this context, it might be reasonable to assume that the marginal costs of information acquisition decline the more customers are already informed. This promises interesting new insights with regard to the strategic information behavior of customers. We leave these questions for future endeavors. Last but not least, our theoretical analysis offers various hypotheses for further experimental studies.

Declaration of Competing Interest

None.

CRediT authorship contribution statement

Peter-J. Jost: Supervision, Methodology, Validation. **Steffen Reik:** Conceptualization, Methodology, Formal analysis, Writing - original draft. **Anna Ressi:** Validation, Writing - original draft, Writing - review & editing, Visualization, Formal analysis.

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[17] We owe the idea of the previous two extensions to an anonymous referee. As providing a complete analysis of this scenario is beyond the scope of the paper, details are not included but can be obtained from the authors upon request.

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