Essays on the Theory of Industrial Organization: Credence Goods, Vertical Relations, and Product Bundling

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Chapter 2

Credence Goods Markets with Heterogeneous Experts

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Abstract

In this paper, we analyze a credence goods market adjusted to health care with regulated prices and heterogeneous experts. Experts are physicians and are assumed to differ in their costs of treating a small problem. We investigate the effects of the cost heterogeneity on the physicians' level of fraud and on the patients' search for second opinions. We find that introducing a fraction of more efficient *low-cost physicians* always increases social welfare, but in some cases only because of a raise in the physician surplus due to the lowered costs and not because of fewer patient searches. When the low-cost physicians' cost advantage is small, imposing a share of low-cost physicians does not change the equilibrium fraud level. When the cost advantage is large, however, changes in the fraud level can occur depending on the share of low-cost physicians, the search rate and the initial level of fraud.

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2.1 Introduction

In a credence goods market, a customer cannot assess *ex post* whether he received the quality he actually needed, whereas an expert for the credence goods knows this quality exactly (Darby and Karni, 1973). Prime examples of credence goods are taxi rides in unknown locations, repair services or medical treatments (Dulleck et al., 2011; Balafoutas et al., 2013; Fong et al., 2014; Mimra et al., 2016a,b). The expert's information advantage over customers may induce incentives for an expert to defraud customers by selling them the wrong quality, i.e. under- or overtreat them, or by charging them an inappropriate price, i.e. overcharge them (Dulleck and Kerschbamer, 2006). The customer's information disadvantage, in turn, might encourage a customer to visit several experts to receive additional opinions about his required quality (Wolinsky, 1993).

We theoretically analyze a credence goods market that is adjusted to a health care market, considering experts to be pyhsicians and customers to be patients. In the literature on credence goods, experts are typically assumed to be homogenous in their costs for fixing a customer's problem. However, Mehrotra et al. (2012) find empirical evidence that more experienced physicians have a lower cost profile than less experienced physicians. Their results indicate that physicians differ in their treatment efficiency. Besides experience there are further characteristics that may lead to physicians being heterogeneous in their performance costs, such as varying educational background or the use of different equipment. Intuitively, one could expect that more efficient experts have weaker incentives to defraud customers than less efficient experts because they may earn higher profits than the less efficient experts by being honest. In order to analyze such effects and relations, we develop a model in which we impose heterogeneity in treatment costs among physicians. More specifically, in our framework a fraction of physicians (called *low-cost physicians*) treats patients that suffer from small problems more efficiently than the remaining physicians (called *high-cost physicians*). Furthermore, we assume that treatment prices are exogenously given because in many health care markets like in Germany prices are regulated (Sülzle and Wambach, 2005).

We finally investigate the following research question in our model: *How does the heterogeneity in treatment costs affect the physicians' overcharging behavior, the patients' search for second opinions and the overall social welfare?* We therefore analyze the impact of differences in efficiency among physicians and of different distributions of high-cost and low-cost physicians in the market on the players' equilibrium strategies.

Our model builds upon the models of Wolinsky (1993) and Sülzle and Wambach (2005), who also analyze the experts' incentives to defraud and the customers' incentives to search. In contrast to our study, they assume that experts are homogenous in treatment costs. Wolinsky (1993) illustrates that with flexible treatment prices, there is no fraud by experts. Then, there either occurs an equilibrium with customer search for second opinions or one without. The size of the customers' search and waiting costs determines which kind of market equilibrium arises. Wolinsky additionally finds that in a setting with fixed prices, there is always fraud in the equilibrium, but there may be no search. Sülzle and Wambach (2005) build upon Wolinsky (1993), but concentrate on exogenous prices and introduce a co-insurance rate for customers. They find that an increase in the co-insurance rate has ambiguous effects on the experts' fraud level and on the customers' search rate in the equilibrium.

In the literature on credence goods exist only a few studies that investigate the experts' fraud incentives and the customers' search for second opinions while assuming experts to be heterogeneous. Marty (1999) examines a market with fixed treatment prices, where he distinguishes between honest experts and opportunistic experts who might defraud customers. He observes that the rejection strategy the customers play and the treatment behavior of the honest experts might prevent an opportunistic expert from cheating all the time. Furthemore, Liu (2011) analyzes a market with endogenous prices in which the experts are either selfish or conscientious, where the selfish type is a pure (monetary) profit-maximizer and a conscientious expert cares about the (monetary) profit and fixing a customer's problem. Liu demonstrates that the presence of a conscientious expert could raise the fraud incentives for a selfish type.

Schneider and Bizer (2017a) extend the model of Pesendorfer and Wolinsky (2003) to a framework with experts who are heterogeneous in their diagnostic abilities. They distinguish between high-skilled and low-skilled experts in the sense that the high-skilled are more qualified in diagnosing a customer correctly than low-skilled experts. Schneider and Bizer find that welfare maximizing equilibria are possible when prices are flexible, but in order to be stable equilibria, a sufficient number of high-skilled experts is required. Hence, when there is only a small number of high-skilled experts, price regulation could make the society better off than price competition amongs experts. Schneider and Bizer (2017b) construct an experiment based on their theoretical framework in Schneider and Bizer (2017a). In their experiment, they highlight that an increase in the share of high-skilled experts raises welfare when prices are fixed. On the contrary, when prices are flexible, market efficiency remains unaffected or diminishes when the share of high-skilled experts rises. In addition, their results indicate that price competition between experts might not have the positive impact on welfare that the theoretical literature predicts.

The consideration of heterogeneity in treatment costs is a rather novel contribution to the credence goods literature. This kind of heterogeneity has been, to the best to our knowledge, only considered in Hilger (2016). Hilger studies a credence goods market with flexible prices, where the experts differ in their treatment costs regarding a major and a small treatment. Hilger shows that when cost functions are not observable by customers, all equilibria are characterized by over- and/or undertreatment but never by complete expert honesty. This is because prices do not signal mark-ups to customers when cost functions are not observable. If cost functions were observable, customers could calculate mark-ups and this would lead to experts posting equal mark-up price vectors. Then, incentives for mistreatment would be eliminated.

There are two major contrasts between Hilger's set-up and ours. First, we assume treatment prices to be exogenous, whereas Hilger considers prices to be flexible. Second, Hilger assumes that customers can verify treatments (*verifiability*) and that experts are liable for providing insufficient treatment (*liability*), while we assume liability but no verifiability. The assumption of verifiability rules out overcharging and the assumption of liability prevents undertreatment.[1] Consequently, in our set-up, there is no undertreatment but overcharging might occur. To conclude, we are the first to study how heterogeneity in treatment costs affects the experts' incentives for overcharging and the first to study how this kind of heterogeneity influences the expert fraud as well as the customer search in a credence goods market with regulated prices.

Our main findings can be summarized as follows. Introducing a share of more efficient low-cost physicians does not necessarily affect the physicians' fraud level or the patients' search rate in comparison to a homogeneous benchmark market with solely high-cost physicians. However, overall welfare, which strongly depends on the patients' search costs, is raised in any case, but in some cases only due to the lowered treatment costs. Given the search rate is not minimal and fraud is not maximal in the benchmark case, we always find changes in the search and fraud level if we introduce a sufficiently large fraction of low-cost physicians and a large cost advantage. With the cost advantage being small, only the patients' search rate may be affected by the heterogeneity, but not the fraud level. When the cost advantage is large and it is introduced for a large share of physicians, welfare and fraud are raised to the maximum. This is an interesting result since the low-cost physicians have weaker fraud incentives than the high-cost physicians. In sum, the effects of imposing a cost advantage on fraud and search are ambiguous and depend on the degree of the efficiency advantage, on the share of imposed low-cost physicians, on the initial search rate and on the original fraud level.

The rest of the paper is organized as follows. The next Section 2.2 introduces the model. We analyze the game for patients and physicians as well as the equilibria in Section 2.3. Section 2.4 concludes.

2.2 The Model

There is a continuum of patients in the market and a large but limited number of physicians N.[2] It is common knowledge that each patient suffers either from a major (M) problem with probability $\alpha \in (0, 1)$ or from a small (S) problem with probability $1 - \alpha$.

[1] Regarding the equal mark-up result, verifiability and liability see Dulleck and Kerschbamer (2006).

[2] We refer to a patient as 'he' and to a physician as 'she'.

A patient knows that he is ill but does not know the type of his problem. In order to have the problem cured, a patient visits a physician to receive a diagnosis. A physician recognizes a patient's problem in any case at no cost and gives the patient a treatment recommendation for either a major or a small treatment. When the patient accepts a treatment recommendation, he pays the price for the recommended treatment. The physician always cures a patient's problem when the patient accepts a recommendation. If the patient rejects a recommendation, he leaves and consults another physician. We assume that a patient does not visit more than two physicians.[3] With every visit, search and waiting costs of $k > 0$ arise for the patient. The prices for treatments are exogenously given and we denote the price for a major treatment as p_M and for a small treatment as p_S, where we assume $p_M > p_S$.[4] The patient derives a benefit of $V > 0$ from having his problem fixed. Finally, a patient's payoff is given by $U = V - p_j - nk$, where $j \in \{S, M\}$ and $n \in \{1, 2\}$ is the number of physicians he visits. We suppose $V > p_j + nk$ such that each patient benefits from having his illness cured. We also suppose $k < p_M - p_S$ such that obtaining a second opinion may be beneficial for a patient.

The physicians differ in their costs for curing a patient suffering from a small problem. More precisely, there are two types of physicians in the market: a share $\delta \in (0, 1)$ of *high-cost (h) physicians* and a share $1 - \delta$ of *low-cost (l) physicians*. For treating a small problem, a high-cost physician bears costs of $c_S^h > 0$ and a low-cost physician costs of $c_S^l = c_S^h - \beta$, where $0 < \beta < c_S^h$. That is, a low-cost physician's costs for fixing a small problem are lower by the amount β in comparison to a high-cost physician's costs. Therefore, β is a low-cost physician's *cost advantage*. Treating a major problem induces the same costs of $c_M > c_S^h$ for both types of physicians.[5] Following Hilger (2016), we presume that the physicians' heterogeneity is common knowledge but that the patients cannot observe the physicians' cost functions. Consequently, a patient is not able to recognize whether a physician is a high-cost or a low-cost type. The relation between prices and costs is described by $p_M = c_M$ and $p_S = c_S^h + e$, where $e > 0$ is a (high-cost physician's) mark-up for treating a patient with a small problem honestly.

A patient knows when he is cured, but he does not know which type of treatment he ultimately has gone under. This means that he cannot verify the received quality. This information asymmetry between a physician and a patient creates incentives for a physician to overcharge patients. A physician could recommend a major treatment to a patient with a small problem and when the patient accepts the recommendation, he pays for the major treatment despite receiving a small treatment. In our model, no undertreatment

[3] This assumption is in line with, for instance, Wolinsky (1993, 1995); Sülzle and Wambach (2005).

[4] We do not consider the patients to be insured. However, introducing a co-insurance rate as in Sülzle and Wambach (2005) would not change our results qualitatively.

[5] Note that patients with major problems are never defrauded in our model since there is no undertreatment, and thus introducing cost heterogeneity regarding a major treatment would not affect the equilibrium outcomes.

or overtreatment take place such that any patient exactly receives the needed treatment. Undertreatment is not considered as we assume physicians to be liable for risking a patient's health. There is no overtreatment because overcharging dominates overtreating in our set-up. Finally, a physician of type $i \in \{l, h\}$ recommends a major treatment to an S-patient with probability $x_i \in [0, 1]$ and provides an honest diagnosis with probability $1 - x_i$. The patients are aware that they might be defrauded and that there can be only overcharging. Hence, a patient accepts a major diagnosis on his first visit with probability $y \in [0, 1]$ and rejects it with probability $1 - y$. An S-treatment recommendation and any diagnosis from the second physician are always accepted, but we suppose that a physician does not know whether it is a patient's first or second visit.

A physician earns the profit π_i per patient. The profit is the (absolute) difference between the treatment price of the accepted treatment and the treatment costs, depending on the actual health state of the patient. If the treatment is rejected by a patient, the physician gains a profit of zero. Treating a patient with small problem honestly generates an *honest profit* of $p_S - c_S^h = e$ for a high-cost physician. For a low-cost physician, the honest profit is greater by the cost advantage β. The *fraud profit*, i.e. the profit for performing a small treatment and charging a major one, is given as $p_M - c_S^h = c_M - c_S^h$ for a high-cost physician and is again greater by β for a low-cost physician. From the assumption $p_M > p_S = c_S^h + e$ follows that $p_M - c_S^h > e$. Thereby, the fraud profit is greater than the honest profit for both types of physicians. However, a fraud diagnosis could be rejected, leaving the physician with no profit, whereas an honest diagnosis regarding a small problem is accepted in any case.

Next, we solve the optimization problems of the patients and physicians in order to derive the equilibria of the game. We focus on symmetric Nash equilibria, where all patients choose the same acceptance strategy y and the same types of physicians (high-cost or low-cost) choose the same recommendation strategy x_i.

2.3 Analysis

2.3.1 Patient Decision

A patient maximizes his expected utility by minimizing his expected costs for being treated. His expected costs are minimized by choosing the optimal acceptance strategy y. Assume that all physicians in the market overcharge patients with small problems with probability $X = \delta X_h + (1 - \delta) X_l$, where X_h is the high-cost physicians' average level of fraud and X_l is the low-cost physicians' average level of fraud. Since a patient cannot detect a physician's cost type, he plays his best strategy given his belief regarding the overall level of fraud X. Ultimately, the patients' symmetric best response correspondence is described by

Lemma 2.1. *For a given $X \in [0,1]$, the patients' symmetric best response correspondence reads*

$$y^*(X) \in \begin{cases} \{0\} & \text{if } X \in (X_1, X_2), \\ [0,1] & \text{if } X \in \{X_1, X_2\}, \\ \{1\} & \text{if } X \in [0, X_1) \cup (X_2, 1], \end{cases}$$

where

$$X_{1,2} = \frac{1}{2}\left(1 - \frac{k}{p_M - p_S}\right) \pm \sqrt{\frac{1}{4}\left(1 - \frac{k}{p_M - p_S}\right)^2 - \frac{\alpha}{1-\alpha}\frac{k}{p_M - p_S}}. \tag{2.1}$$

Proof. See Lemma 1 in Sülzle and Wambach (2005) and the proof therein. □

According to the lemma above, patients accept a major diagnosis on their first visit in any case when the physicians barely overcharge or when they overcharge a lot. In the former case, the diagnosis on the first visit is likely to be correct. In the second case, a second diagnosis would most likely be dishonest, just as the first one. Given the fraud level is at a medium level (between X_1 and X_2), there is a good chance that one out of the two physicians is honest. For that reason, receiving a second opinion may pay off for a patient in this situation. As a consequence, the patients always reject a recommendation for a major treatment on their first visit for medium values of X.

2.3.2 Physician Choice

We now turn to the analysis of the physicians' optimization problems. In the following, we suppose $\frac{p_M - c_S^h(2-y)}{2-y} < e < \frac{p_M - c_S^h}{2-y}$ (for $y < 1$) because we analyze all possible settings with fraud and the effect of the physicians' heterogeneity on market outcomes.[6]

A physician can only gain a positive profit when facing a patient with a small problem since the price of an M-treatment, p_M, equals the costs of an M-treatment, c_M. When facing an S-patient, a physician of type i maximizes her expected profit by choosing the optimal overcharging strategy x_i. Suppose that all patients accept a major diagnosis on their first visit with probability y and that all other physicians cheat with probability X. Then, an individual physician's expected profit per S-patient is given by

$$\pi_i = (1 - x_i)\left(p_S - c_S^i\right) + x_i \frac{y + X(1-y)}{1 + X(1-y)}\left(p_M - c_S^i\right). \tag{2.2}$$

If an S-patient visits, a physician defrauds the patient with probability x_i and is honest with probability $1 - x_i$. The physician always gains a profit of $p_S - c_S^i$ given she diagnoses the patient honestly. She earns the fraud profit $p_M - c_S^i$ with probability $\frac{y+X(1-y)}{1+X(1-y)}$

[6]For the reasoning of this assumption see Appendix 2.5.1 and 2.5.2. For simplicity, we restrict the graphical illustration of our results to numerical parameters where $e > \frac{p_M - c_S^h(2-y)}{2-y}$ is always fulfilled only for $y \leq \frac{e+\beta-\delta(p_M - c_S^h - e)}{p_M - c_S + \beta - \delta(p_M - c_S^h - e)}$.

when recommending dishonestly to the patient. This probability considers that a share $\frac{1}{1+X(1-y)}$ of patients with small problems are on their first visit and hence accept a major diagnosis with probability y. It additionally considers that a fraction $\frac{X(1-y)}{1+X(1-y)}$ of patients with small problems already consults a second physician and, consequently, accepts a fraudulent diagnosis with probability 1.

A physician defrauds the patient if and only if cheating yields a higher profit than treating honestly. By Equation (2.2), we can therefore derive that a physician recommends a major treatment to a patient with a small problem with probability 1 (0) if

$$p_S - c_S^i < (>) \frac{y + X(1-y)}{1 + X(1-y)} \left(p_M - c_S^i\right). \tag{2.3}$$

Given both sides of Expression (2.3) are equal, a physician is just indifferent between defrauding and diagnosing the patient honestly. Lemma 2.2 summarizes our findings regarding an individual physician's fraud incentives.

Lemma 2.2. *Let (X, y) be given. Then, a physician's individual best response reads*

$$x_i^*(X,y) \in \begin{cases} \{0\} & \text{if } p_S > \frac{y+X(1-y)}{1+X(1-y)} p_M + c_S^i \frac{1-y}{1+X(1-y)}, \\ [0,1] & \text{if } p_S = \frac{y+X(1-y)}{1+X(1-y)} p_M + c_S^i \frac{1-y}{1+X(1-y)}, \\ \{1\} & \text{if } p_S < \frac{y+X(1-y)}{1+X(1-y)} p_M + c_S^i \frac{1-y}{1+X(1-y)}. \end{cases}$$

It follows from the physician's individual best response that the low-cost and high-cost physicians have heterogeneous fraud incentives in most situations:

Lemma 2.3. *A low-cost physician has weaker fraud incentives than a high-cost physician for $y \in [0, 1)$. For $y = 1$, the fraud incentives of both types of physicians coincide.*

Proof. Assume $y \in [0, 1)$. Then, a physician of type i diagnoses an S-patient honestly when $p_S > \frac{y+X(1-y)}{1+X(1-y)} p_M + c_S^i \frac{1-y}{1+X(1-y)} =: \overline{p}_S^i$. We have $\overline{p}_S^h > \overline{p}_S^l$ due to $c_S^h > c_S^l$ and $\frac{1-y}{1+X(1-y)} > 0$. Thus, in order to keep a high-cost physician from cheating, a larger price p_S is needed than for a low-cost physician. If $y = 1$, the term $c_S^i \frac{1-y}{1+X(1-y)}$ becomes zero and then the fraud incentives are the same for both types of physicians. □

We derive from Lemma 2.3 that for $y \in [0, 1)$, a low-cost physician treats honestly given the high-cost physicians are honest or indifferent between cheating and being honest. Additionally, we derive that a high-cost physician cheats when the low-cost physicians defraud or are indifferent given $y \in [0, 1)$.

We next determine the symmetric best response for the high-cost physicians and the symmetric best response for the low-cost physicians, starting with the high-cost types.

High-Cost Physicians

The following Lemma 2.4 characterizes how the high-cost physicians' symmetric best response correspondence, X_h^*, depends on the share of high-cost physicians, δ, for a given low-cost physicians' fraud level, X_l, and a given patients' acceptance strategy, y.[7]

Lemma 2.4. *For a* large share of high-cost physicians*, i.e.* $\delta > \frac{e-y(p_M-c_S^h)}{(1-y)(p_M-c_S^h-e)}$*, the high-cost physicians' symmetric best response correspondence is given by*

$$X_h^*(X_l,y) \in \begin{cases} \left\{0, \frac{e-y(p_M-c_S^h)}{\delta(1-y)(p_M-c_S^h-e)}, 1\right\} & \text{if } X_l \in \{0\} \text{ and } y \in \left[0, \frac{e}{p_M-c_S^h}\right], \\ \{1\} & \text{else.} \end{cases}$$

For a small or medium share δ*, i.e.* $\frac{e-y_2(p_M-c_S^h)}{(1-y_2)(p_M-c_S^h-e)} \leq \delta \leq \frac{e-y_1(p_M-c_S^h)}{(1-y_1)(p_M-c_S^h-e)}$*, the high-cost physicians' symmetric best response correspondence is given by*

$$X_h^*(X_l,y) \in \begin{cases} \{0\} & \text{if } X_l \in \{0\} \text{ and } y \in \left[0, \frac{e-\delta(p_M-c_S^h-e)}{p_M-c_S^h-\delta(p_M-c_S^h-e)}\right], \\ \left\{0, \frac{e-y(p_M-c_S^h)}{\delta(1-y)(p_M-c_S^h-e)}, 1\right\} & \text{if } X_l \in \{0\} \text{ and } y \in \left[\frac{e-\delta(p_M-c_S^h-e)}{p_M-c_S^h-\delta(p_M-c_S^h-e)}, \frac{e}{p_M-c_S^h}\right], \\ \{1\} & \text{else,} \end{cases}$$

where $y_1 := y \in \left(0, \frac{e-\delta(p_M-c_S^h-e)}{p_M-c_S^h-\delta(p_M-c_S^h-e)}\right]$ *and* $y_2 := y \in \left[\frac{e-\delta(p_M-c_S^h-e)}{p_M-c_S^h-\delta(p_M-c_S^h-e)}, 1\right)$.

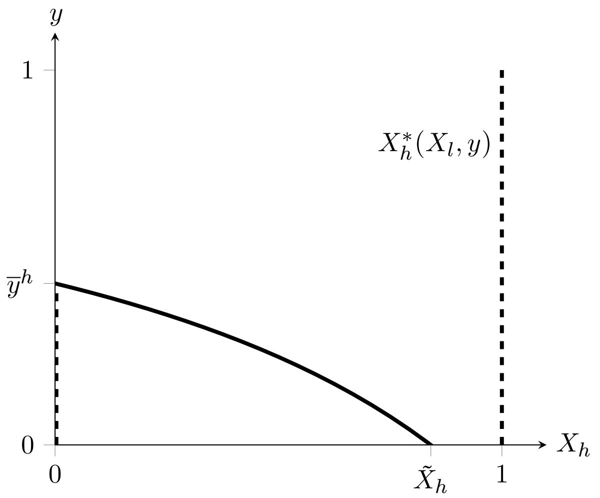
Proof. See Appendix 2.5.1. □

First of all note that $\frac{e-y(p_M-c_S^h)}{(1-y)(p_M-c_S^h-e)} < 0$ for $y > \frac{e}{p_M-c_S^h}$. As $\delta > 0$, we cannot simply assume $\delta < \frac{e-y(p_M-c_S^h)}{(1-y)(p_M-c_S^h-e)}$ and, consequently, all relevant cases of δ are covered by Lemma 2.4. Also, only when the low-cost physicians treat honestly, can a high-cost physician's best strategy be to treat honestly or to randomize between cheating and honest diagnoses. Otherwise, a high-cost physician always cheats, as explained above. Therefore, the following intuition for the high-cost physicians' symmetric best response refers only to the case with $X_l = 0$ (Figure 2.1). Then, if patients accept a major diagnosis sufficiently often, i.e. $y \geq \frac{e}{p_M-c_S^h} =: \overline{y}^h$, it is always a high-cost physician's best strategy to defraud her S-patients. With a large share of high-cost physicians in the market and $y \leq \overline{y}^h$ or with a small or medium share of high-cost physicians as well as y between $\tilde{y}^h := \frac{e-\delta(p_M-c_S^h-e)}{p_M-c_S^h-\delta(p_M-c_S^h-e)}$ and $\overline{y}^h$, a high-cost physician's best response corresponds to the defrauding behavior of the other high-cost types.

Assume that patients only sometimes accept a major diagnosis on their first visit so that $y \leq \overline{y}^h$. In this situation, if the share of high-cost physicians is large (Figure 2.1a), it is a high-cost physician's best response to cheat given all other high-cost physicians cheat ($X_h = 1$). In this case, there are so many cheating physicians in the market that many

[7] We depict the physicians' best response correspondence following Sülzle and Wambach (2005).

patients with small problems are on their second visit. These patients would accept any diagnosis and thus a high-cost physician cheats. In contrast, when all other high-cost physicians treat honestly ($X_h = 0$), there are too many patients with small problems on their first visit. These patients would reject a major diagnosis with a relatively high probability, due to the low to medium acceptance rate. Hence, an individual high-cost physician prefers to treat honestly as well. There is also a certain region (depicted by the black bold solid line in Figure 2.1a), where all high-cost physicians are indifferent between cheating and treating honestly for a large δ and $y \leq \overline{y}^h$.



(a) Large δ **(b)** Small or medium δ

Figure 2.1: High-cost physicians' symmetric best response correspondence given $X_l = 0$. Notice that $\tilde{X}_h := \frac{e}{\delta(p_M - c_S^h - e)}$.

If the share of high-cost physicians is small or medium (Figure 2.1b), it is a high-cost physician's best strategy to diagnose honestly for a patients' acceptance rate below $\tilde{y}^h$. In this situation, there are several honest low-cost physicians in the market and, consequently, several patients with small problems are on their first visit. Thus, cheating is not profitable if the patients reject very often a major diagnosis on their first visit. When $y \in \left[\tilde{y}^h, \overline{y}^h\right]$, a high-cost physician cheats given all other high-cost physicians cheat too because of a larger acceptance rate and sufficiently many patients on a second visit. However, even at this medium acceptance rate, it is a high-cost physician's best response to be honest when all other physicians diagnose honestly because of too many patients on their first visit. If the patients' acceptance rate is medium, then there is again a region in which all high-cost physicians randomize (the black bold solid line in Figure 2.1b).

Low-Cost Physicians

We now turn to the low-cost physicians' defrauding behavior. Lemma 2.5 illustrates how the low-cost physicians' symmetric best response, X_l^*, depends on the cost advantage β

and on the share of high-cost physicians in the market, δ, for a given high-cost physicians' level of fraud, X_h, and a given y.

Lemma 2.5. *Given a* small cost advantage*, i.e.* $\beta < \frac{p_M - c_S^h - e(2-y)}{1-y}$*, and* $\delta > \frac{e+\beta}{p_M - c_S^h - e}$*, the low-cost physicians' symmetric best response correspondence is given by*

$$X_l^*(X_h, y) \in \begin{cases} \{0\} & \text{if } X_h \in \{0\} \text{ or } X_h \in (0,1), \\ \{1\} & \text{if } X_h \in \{1\}. \end{cases}$$

Given a small cost advantage β *and* $\delta < \frac{e+\beta}{p_M - c_S^h - e}$*, the low-cost physicians' symmetric best response correspondence is given by*

$$X_l^*(X_h, y) \in \begin{cases} \{0\} & \text{if } X_h \in \{0\} \text{ or } X_h \in (0,1), \\ \left\{0, \frac{e+\beta-y(p_M-c_S^h+\beta)}{(1-\delta)(1-y)(p_M-c_S^h-e)} - \frac{\delta}{1-\delta}, 1\right\} & \text{if } X_h \in \{1\} \text{ and } y \in \left[0, \tilde{y}^l\right], \\ \{1\} & \text{if } X_h \in \{1\} \text{ and } y \in \left[\tilde{y}^l, 1\right]. \end{cases}$$

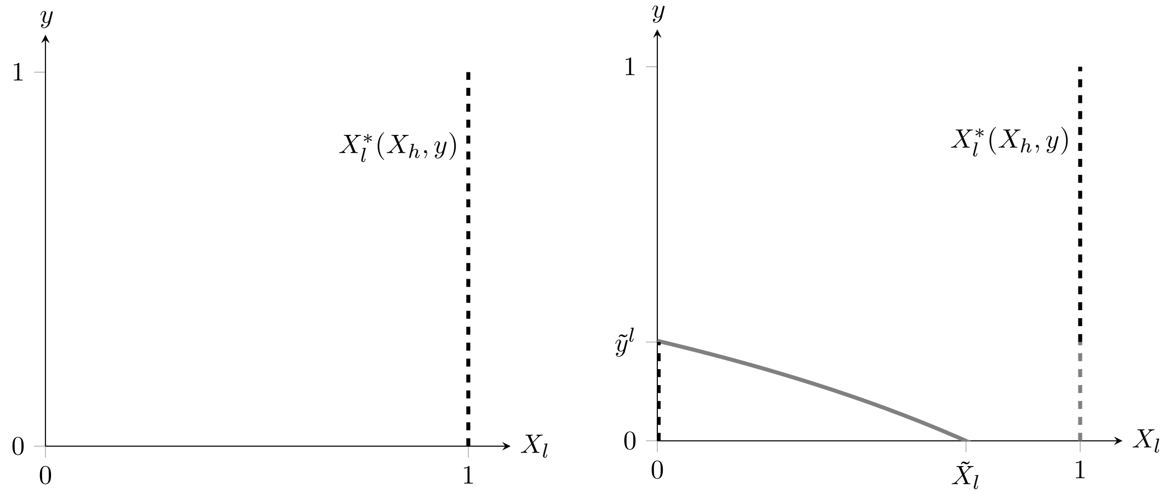
Given a large cost advantage*, i.e.* $c_S^h > \beta > \frac{p_M - c_S^h - e(2-y)}{1-y}$*, the low-cost physicians' symmetric best response correspondence is given by*

$$X_l^*(X_h, y) \in \begin{cases} \{0\} & \text{if } X_h \in \{0\} \text{ or } X_h \in (0,1), \\ \{0\} & \text{if } X_h \in \{1\} \text{ and } y \in \left[0, \tilde{y}^l\right], \\ \{1\} & \text{if } X_h \in \{1\} \text{ and } y \in \left[\tilde{y}^l, 1\right], \end{cases}$$

where $\tilde{y}^l := \frac{e+\beta-\delta(p_M-c_S^h-e)}{p_M-c_S^h+\beta-\delta(p_M-c_S^h-e)}$.

Proof. See Appendix 2.5.2. □

With honest or indifferent high-cost physicians, it is always a low-cost physician's best response to treat honestly. Hence, the following intuition for the low-cost physicians' symmetric best response refers only to the case in which the high-cost physicians always cheat ($X_h = 1$, Figure 2.2). The fraud profit is even greater for a low-cost physician than for a high-cost physician, due to the low-cost physician's cost advantage β. Thus, when all high-cost physicians cheat and patients accept a major diagnosis on their first visit relatively often such that $y \geq \frac{e+\beta-\delta(p_M-c_S^h-e)}{p_M-c_S^h+\beta-\delta(p_M-c_S^h-e)} =: \tilde{y}^l$, a low-cost physician prefers to always defraud patients with small problems. Moreover, given a small cost advantage and a *huge share of high-cost physicians*, i.e. $\delta > \frac{e+\beta}{p_M-c_S^h-e}$ (Figure 2.2a), a low-cost physician cheats irrespective of the other low-cost physicians' defrauding behavior or the patients' acceptance rate. In this case, there are many S-patients on their second visit due to the many cheating high-cost types and the cost advantage is always small. As consequence, defrauding is a low-cost physician's best response in any case.



(a) Small β and $\delta > \frac{e+\beta}{p_M - c_S^h - e}$ **(b)** Small or large β and $\delta < \frac{e+\beta}{p_M - c_S^h - e}$

Figure 2.2: Low-cost physicians' symmetric best response correspondence given $X_h = 1$. Notice that $\tilde{X}_l := \frac{e+\beta}{(1-\delta)(p_M - c_S^h - e)} - \frac{\delta}{1-\delta}$.

However, given $\delta < \frac{e+\beta}{p_M - c_S^h - e}$ (Figure 2.2b), a small cost advantage (i.e. the physicians' best response includes the gray lines in Figure 2.2b) and a patients' acceptance rate below $\tilde{y}^l$, a low-cost physician's best response corresponds to the behavior of the other low-cost physicians. In this situation, it is a low-cost physician's best strategy to overcharge when all other low-cost physicians overcharge ($X_l = 1$) and to diagnose honestly when all other low-cost physicians are honest ($X_l = 0$). If all physicians cheat, there are sufficiently many patients with small problems on their second visit such that overcharging is beneficial. By contrast, when only the high-cost physicians defraud, there are too few patients with small problems consulting a second physician for cheating to be profitable for a low-cost physician. For a small cost advantage, $\delta < \frac{e+\beta}{p_M - c_S^h - e}$ and $y \leq \tilde{y}^l$, there is also a region where all low-cost physicians randomize between fraudulent and honest diagnoses (depicted by the gray bold solid in Figure 2.2b). If the cost advantage is large, a low-cost physician always treats honestly for $y \leq \tilde{y}^l$ independent of δ, even when the high-cost physicians cheat. The large cost advantage leads to a high certain honest profit and therefore a low-cost physician prefers to treat honestly given patients often look for a second opinion.

2.3.3 Equilibrium Analysis

We now determine and analyze all kinds of equilibria that can occur in our model. We first investigate how the two types of physicians' symmetric best responses can be combined to a physicians' joint best response correspondence, that constitutes the overall market level of fraud X^*. Then we combine the physicians' joint best response with the patients' symmetric best response correspondence y^* in order to determine the Nash equilibria.

We compare the equilibrium outcomes of each case with heterogeneous physicians to a benchmark market, where the physicians are homogeneous in the sense that all physicians are high-cost physicians ($\delta = 1$).[8] The comparison allows us to study the influence of the heterogeneity in treatment costs on the physicians' level of fraud, the patients' search rate and the overall market welfare. There are five joint physicians' best responses that can be part of the physicians' joint best response correspondence as stated by

Corollary 2.1. *Depending on the acceptance rate y, the market level of fraud X, the distribution of high-cost and low-cost physicians as well as the cost advantage β, the following physicians' joint best responses can occur as part of a Nash equilibrium:*

1. *Both types of physicians treat their patients honestly.*
2. *The low-cost types treat their patients honestly and the high-cost types are indifferent between honest and fraudulent diagnoses for patients with small problems.*
3. *The low-cost types treat their patients honestly and the high-cost types defraud patients with small problems.*
4. *The low-cost types are indifferent between honest and fraudulent diagnoses and the high-cost types defraud patients with small problems.*
5. *Both types of physicians defraud patients with small problems.*

The corollary follows directly from Lemma 2.4 and Lemma 2.5.

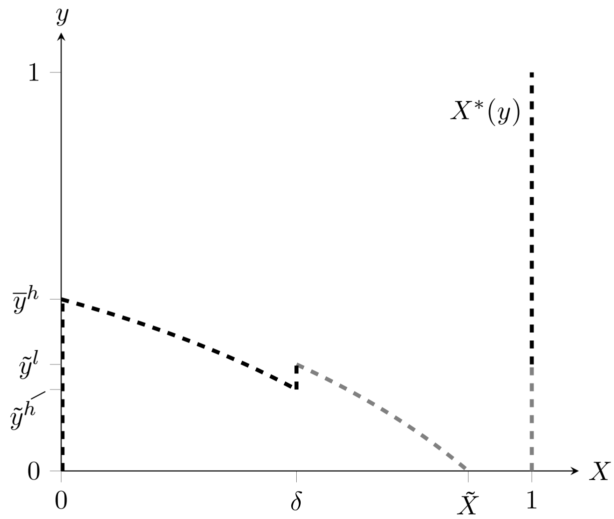


Figure 2.3: Physicians' joint best response correspondence given a small or medium δ. Notice that $\tilde{X} := \frac{e+\beta}{p_M - c_S^h - e}$.

[8]The equilibria of this benchmark case are qualitatively equivalent to the equilibria of Sülzle and Wambach (2005) with $X_2 < \frac{e}{p_M - p_S}$.

The joint best response correspondence (Figure 2.3) is affected by the distribution of high-cost and low-cost physicians in the market as well as by the characteristics of the cost advantage β. It is possible that all high-cost physicians defraud and all low-cost types are indifferent between defrauding and treating honestly only when $\delta < \frac{e+\beta}{p_M - c_S^h - e}$ and the cost advantage is small (i.e. the joint best response correspondence includes the gray lines in Figure 2.3 and in Figures 2.4b - 2.4d).[9] Moreover, the combination of defrauding high-cost physicians and honest low-cost physicians is an option for a best response only if $\delta < \frac{e+\beta}{p_M - c_S^h - e}$ but irrespective of β. In sum, if $\delta > \frac{e+\beta}{p_M - c_S^h - e}$, only cases 1, 2 and 5 of Corollary 2.1 are part of the joint best response correspondence.
Lemma 2.6 describes the conditions for the mutual compatibility of the best responses of the two types of physicians that is necessary for the stability of the joint best response.

Lemma 2.6. *A mutually compatible physicians' joint best response is given by a high-cost physician's best response for $X < \delta$ and by a low-cost physician's best response for $X > \delta$. For $X = \delta$, a mutually compatible joint best response is given by the convex combination $\lambda \tilde{y}^l + (1-\lambda)\tilde{y}^h > 0$, where $\lambda \in [0, 1]$, if the convex combination exists.*

Proof. See Appendix 2.5.3. □

Next, we combine the patients' symmetric best response correspondence (depicted by the black bold solid lines in Figure 2.4) with the physicians' joint best response correspondence for different distributions of high-cost and low-cost physicians in the market (see Figures 2.4a - 2.4d). We compare the various heterogeneous cases to the homogeneous case. Proposition 2.1 summarizes the impact of introducing physician heterogeneity regarding treatment costs on the fraud level and on the search rate in the equilibrium.[10]

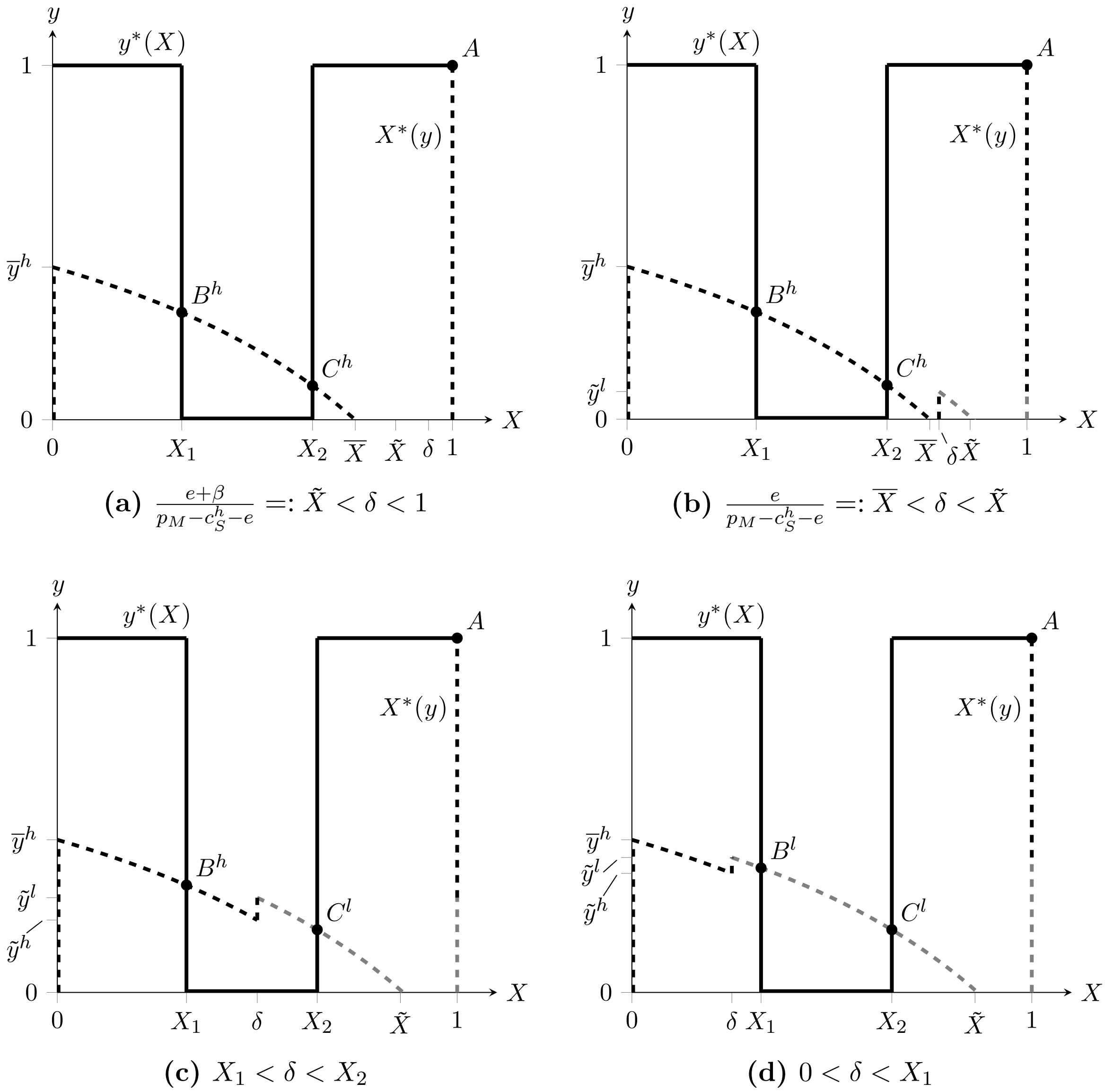
Proposition 2.1. *When the reference market with homogeneous physicians is in a pure-strategy equilibrium, denoted A, where all physicians always defraud patients with small problems and no patient searches for a second opinion, then introducing heterogeneity in treatment costs regarding a small problem does not affect the physicians' market level of fraud X^* or the patients' acceptance rate y^*.*
Given the homogeneous market is in one of two mixed-strategy equilibria, denoted B and C, where physicians defraud and patients search with a positive probability, then introducing heterogeneity in treatment costs has ambiguous effects on the physicians' level of fraud and the patients' acceptance rate.

Social welfare is defined as the sum of patient and physician surplus. When no patient looks for a second opinion, welfare is maximized. This is because in our model the demand is completely inelastic as every patient is ultimately treated (sufficiently). Consequently, the pure-strategy equilibrium A is welfare optimal even though the fraud level is at

[9]Notice that the case depicted in Figure 2.4a can only occur with a small cost advantage.
[10]Notice that we concentrate on local changes regarding the impact of heterogeneity on equilibria.

its maximum in A. When the homogeneous reference market is in equilibrium A and we introduce lower treatment costs for a fraction of physicians, we do not observe any changes in the fraud level or in the patients' search rate (compare Figure 2.4). The reason for this is that the cost advantage increases the low-cost physicians' fraud profit, which is gained in any case in equilibrium A. Yet, welfare is higher in A in the heterogeneous market than in the homogeneous setting. This is because the fraud profit of at least one physician is raised and therefore the aggregate physician surplus is raised.

In the remainder of the section, we analyze the impact of the cost heterogeneity on mixed-strategy equilibria. We regard any equilibrium where at least one player plays a mixed strategy as a mixed-strategy equilibrium. We use the superscripts h and l for the mixed-strategy equilibria, where the mutually compatible physicians' joint best response is determined by the high-cost or the low-cost physicians' best response, respectively.



(a) $\frac{e+\beta}{p_M - c_S^h - e} =: \tilde{X} < \delta < 1$

(b) $\frac{e}{p_M - c_S^h - e} =: \overline{X} < \delta < \tilde{X}$

(c) $X_1 < \delta < X_2$

(d) $0 < \delta < X_1$

Figure 2.4: Equilibrium settings with different distributions of high-cost and low-cost physicians

First consider that a very small share of low-cost physicians is introduced and thus a huge share of high-cost physicians remains in the market such that $\delta > \frac{e+\beta}{p_M - c_S^h - e}$ (Figure 2.4a), which implies a small cost advantage. Then, the equilibrium setting of the heterogeneous market is equivalent to the reference case. Accordingly, there are no changes in the fraud level or in the patients' acceptance rate as a consequence of incorporating lowered costs for a fraction of physicians. This observation is somewhat surprising since the low-cost physicians have weaker fraud incentives than the high-cost physicians for $y \in [0, 1)$ and thus treat honestly when the high-cost physicians are indifferent. Consequently, the high-cost physicians compensate the low-cost physicians' honest behavior in B^h or C^h by cheating more on average than all physicians in B or C, respectively. However, social welfare is higher in B^h and C^h than in B and C, respectively, due to the lowered treatment costs. Be aware that we always find this kind of increase in welfare when the equilibria remain unchanged otherwise. When the share of high-cost physicians is a slightly smaller, i.e. $\frac{e}{p_M - c_S^h - e} < \delta < \frac{e+\beta}{p_M - c_S^h - e}$ (Figure 2.4b), which implies $\delta > X_2$, the qualitative differences in market results between this heterogeneous case and the homogeneous benchmark case are the same as for $\delta > \frac{e+\beta}{p_M - c_S^h - e}$.

Imagine now that there is a balanced distribution of both types of physicians so that $X_1 < \delta < X_2$ (Figure 2.4c). In this case, there is no equilibrium C^h. When there is a medium share of (honest) low-cost physicians, being honest is more profitable than cheating for a high-cost physician at a relatively small patients' acceptance rate like the one in C^h, because there are too many patients with small problems on their first visit. Given a small cost advantage, a new mixed-strategy equilibrium, denoted C^l, emerges. In this equilibrium, all high-cost physicians cheat, all low-cost physicians and all patients randomize. Patients in C^l accept a major diagnosis on their first visit more often than in C^h/C but the fraud level X^* in C^l is the same as in C^h/C. This illustrates that at a slightly higher patients' acceptance rate than in C^h, i.e. at $\tilde{y}^l$, it can be profitable for high-cost and low-cost physicians to overcharge their patients when there is a balanced distribution of both types of physicians. By contrast, when the cost advantage is large, a low-cost physician does not cheat at all for $y \leq \tilde{y}^l$ in this setting. Hence, there is neither an equilibrium C^h nor an equilibrium C^l given a large cost advantage and a medium δ. Thereby, the market equilibrium is either B^h or A. Equilibrium B^h exists in this situation because for a high-cost physician it is still profitable to defraud sometimes at the medium acceptance rate in B^h.

In conclusion, if we are in equilibrium C in the homogeneous market and introduce a medium share of low-cost physicians, then the patients' acceptance rate always rises. When the cost advantage is small, C^l becomes the new market equilibrium and thus the level of fraud is not changed compared to C. If the cost advantage is large, B^h or A, which both have a higher patients' acceptance rate than C, become the new equilibrium. This implies that we either obtain less fraud or more fraud and that welfare could be maximized. We further observe that implementing a fraction of physicians with reduced treatment costs might maximize the fraud level too, which is in clear contrast to intuition. Moreover, starting in equilibrium B and incorporating a cost advantage for a medium share of physicians does not have any impact on the patients' search rate or the physicians' fraud level, but welfare is raised due to the increase in physician surplus.

Suppose now that there is a relatively small share of high-cost physicians such that $0 < \delta < X_1$ (Figure 2.4d).[11] In this market, there is neither an equilibrium B^h nor an equilibrium C^h. This is because at the medium acceptance rate in B^h diagnosing honestly is more beneficial than cheating for a high-cost physician when there are many honest low-cost physicians. If the cost advantage is small, another new mixed-strategy equilibrium, denoted B^l, occurs, in which the high-cost physicians cheat and the low-cost physicians as well as the patients are indifferent. The search rate in B^l is lower than in B^h/B and the level of fraud is the same in the three equilibria. Given the cost advantage is large, the only remaining equilibrium is the pure-strategy equilibrium A. This means that if the homogeneous reference market is in any mixed-strategy equilibrium, implementing a large share of low-cost physicians always raises the patients' acceptance rate: if we introduce a large share of low-cost physicians with a small cost advantage, B^l or C^l become the new market equilibrium when the homogeneous market equilibrium was B or C, respectively. This implies that the level of overcharging is not influenced by the cost heterogeneity. If a large cost advantage for a large share of physicians is incorporated, then the patients' search level is always minimized and the physicians' level of fraud always maximized.[12]

2.4 Conclusion

In this paper, we theoretically examine how heterogeneity among physicians with respect to their treatment efficiency affects the physicians' level of fraud, the patients' search for second opinions and social welfare in a credence goods market that is adapted to a health care market with regulated prices. For our benchmark case, we consider a homogeneous setting, where all physicians are equally efficient and represent high-cost physicians.

We find that introducing a treatment cost advantage regarding small problems for a share of physicians (called low-cost physicians) always raises social welfare. However, in some cases welfare is only raised because of the reduced treatment costs, which ceteris paribus lead to higher physician profits. If the homogeneous market is in an equilibrium with maximum fraud and no search at all, introducing low-cost physicians into the market does not affect the physicians' fraud level or the patients' search rate. This is because a physician's fraud profit is positively affected by lowered treatment costs concerning a small problem.

[11] The equilibrium constellation with $\delta = 0$ is equivalent to the constellation with $0 < \delta < X_1$.

[12] Further equilibrium settings, in which continua of equilibria arise, are depicted in Appendix 2.5.4.

Furthermore, also when the benchmark market is in an equilibrium, where physicians sometimes cheat and patients sometimes search for second opinions, then the patients' search rate and the physicians' level of fraud remain unchanged when we incorporate only a small fraction of low-cost physicians. If there are only a few low-cost physicians in the market, the remaining high-cost physicians, who have mostly stronger fraud incentives than the low-cost physicians, continue cheating with a positive probability and compensate the low-cost physicians' honest behavior by cheating more. When we introduce sufficiently many low-cost physicians in equilibria, where physicians sometimes cheat and patients sometimes search, the patients' search level is always lowered. Still, only considering a large cost advantage might change the equilibrium level of fraud. The impact on the fraud level is ambiguous and depends on the share of introduced low-cost physicians as well as on the initial and the new equilibrium. In fact, the level of fraud could be maximized by inserting heterogeneity in treatment efficiency, which clearly contradicts our intuition.

To sum up, unless the patients' search rate is already minimized, implementing a small cost advantage for a large share of physicians always reduces the patients' search rate. As a consequence, social welfare is increased due to the raise in the physician surplus and the reduction in the patients' search costs. By contrast, introducing a large cost advantage for a small share of physicians does not change the search rate at all. Therefore, from an efficiency perspective, implementing a small cost advantage for a large share of physicians might be more beneficial than incorporating a large cost advantage for a small share of physicians.

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2.5 Appendix

2.5.1 Proof of Lemma 2.4

First of all note that Sülzle and Wambach (2005) illustrate that with $e \geq \frac{p_M - c_S^h}{2-y}$ and $y \leq \frac{e}{p_M - c_S}$, there are no fraud incentives for (high-cost) physicians, but we do not analyze the impact of e and we analyze all settings with fraud. Therefore, we impose the assumption $e < \frac{p_M - c_S^h}{2-y}$ in our model.
It follows from the individual best response in Lemma 2.2 and from Lemma 2.3 that when the low-cost physicians cheat ($X_l = 1$) or randomize between cheating and being honest ($X_l \in (0,1)$), the high-cost physicians always overcharge patients with small problems. Thus, in what follows, we analyze the high-cost physicians' symmetric best response only for a situation where all low-cost physicians are honest ($X_l = 0$). We derive the symmetric best response for the high-cost physicians from the individual best response of a high-cost type.

Following Sülzle and Wambach (2005), we consider three situations regarding the patients' acceptance strategy, y:

1. $y = 1$. Each patient always accepts a major diagnosis on his first visit. Setting $y = 1$ in (2.3) and rearranging leads to

$$e < p_M - c_S^h. \tag{2.4}$$

   Obviously, if all patients always accept a recommendation for a major treatment on their first visit, each high-cost physician always defrauds patients with small problems since the fraud profit is larger than the honest profit.

2. $y = 0$. Each patient rejects a major diagnosis on his first visit in any case. Substituting $y = 0$ and $X = \delta X_h$ into (2.3) and rearranging yields

$$e \left\{ \begin{array}{c} > \\ = \\ < \end{array} \right\} \frac{\delta X_h}{1 + \delta X_h} \left(p_M - c_S^h \right). \tag{2.5}$$

   An individual high-cost physician's best response depends on the other high-cost physicians' defrauding strategy. Therefore, we consider three different cases regarding the other high-cost physicians' level of fraud, X_h:

   (a) $X_h = 0$. All other high-cost physicians always treat honestly. Setting $X_h = 0$ in (2.5) shows that a high-cost physician is honest given all other physicians are honest if and only if

$$e > 0. \tag{2.6}$$

When all other physicians are honest, an individual high-cost physician treats patients with small problems honestly as well. In that case, each patient with a small problem is on his first visit and since $y = 0$ would reject a recommendation for an M-treatment with certainty. Thus, a high-cost physician plays $x_h = 0$.

(b) $X_h = 1$. All other high-cost physicians defraud patients with small problems. By substituting $X_h = 1$ into (2.5) and rearranging, we obtain that an individual high-cost physician defrauds patients with a small problem as well if and only if

$$\delta > \frac{e}{p_M - c_S^h - e}. \tag{2.7}$$

This means that if the share of high-cost physicians is sufficiently large and all other high-cost physicians cheat, it is the best response of a single high-cost physician to cheat too, i.e. to play $x_h = 1$. In this situation, there are many patients with small problems on their second visit and, consequently, would accept any diagnosis. However, if $\delta < \frac{e}{p_M - c_S^h - e}$ (note that $p_M > c_S^h + e = p_S$), a high-cost physician does not cheat but plays $x_h = 0$. In that situation, there are too many patients with small problems on their first visit, due to the larger share of honest low-cost physicians.

(c) $X_h \in (0, 1)$. All other high-cost physicians randomize between defrauding patients with small problems and being honest. A symmetric best response requires an individual high-cost physician to randomize too. Rearranging (2.5) with an equal sign and solving for X_h shows that a single high-cost physician is indifferent too if and only if

$$X_h = \frac{e}{\delta(p_M - c_S^h - e)} =: \tilde{X}_h. \tag{2.8}$$

For $X_h > \tilde{X}_h$, the high-cost physician prefers to cheat and for $X_h < \tilde{X}_h$, she prefers to diagnose honestly. Note that for $X_h \in (0, 1)$ to be a candidate for a best response, $\delta > \frac{e}{p_M - c_S^h - e}$ must hold. In case $\delta < \frac{e}{p_M - c_S^h - e}$, we get $\tilde{X}_h > 1$ and thus we have $X_h < \tilde{X}_h$. Then, a high-cost physician would deviate and be honest for the same reasons as above.

3. $y \in (0, 1)$. All patients randomize between accepting and rejecting a major diagnosis on their first visit. Substituting $X = \delta X_h$ and rearranging Inequality (2.3) with an equal sign yields

$$y(p_M - c_S^h) + \delta X_h (1 - y)(p_M - c_S^h - e) - e = 0. \tag{2.9}$$

Again, we consider three cases regarding the other high-cost physicians' defrauding behavior:

(a) $X_h = 0$. Setting $X_h = 0$ and rearranging (2.9) with an inequality sign shows that an individual high-cost physician is honest as well if and only if

$$y < \frac{e}{p_M - c_S^h} =: \overline{y}^h. \tag{2.10}$$

Consequently, being honest is a high-cost physician's best response for low values of y, i.e. for $y < \overline{y}^h$. When $y > \overline{y}^h$, a high-cost physician deviates and cheats. Notice that for $y = \overline{y}^h$, she is just indifferent.

(b) $X_h = 1$. If all other high-cost physicians cheat, an individual high-cost physician cheats as well if and only if

$$y(p_M - c_S^h) + \delta(1-y)(p_M - c_S^h - e) - e > 0. \tag{2.11}$$

Condition (2.11) is satisfied if $\delta > \frac{e-y(p_M-c_S^h)}{(1-y)(p_M-c_S^h-e)}$. Now consider the setting where it holds that $\frac{e-y_2(p_M-c_S^h)}{(1-y_2)(p_M-c_S^h-e)} \leq \delta \leq \frac{e-y_1(p_M-c_S^h)}{(1-y_1)(p_M-c_S^h-e)}$. Notice that we define $y_1 := y \in \left(0, \frac{e-\delta(p_M-c_S^h-e)}{p_M-c_S^h-\delta(p_M-c_S^h-e)}\right]$ and $y_2 := y \in \left[\frac{e-\delta(p_M-c_S^h-e)}{p_M-c_S^h-\delta(p_M-c_S^h-e)}, 1\right)$. Then for the values of y_1, condition (2.11) is not fulfilled and it is a high-cost physician's best strategy to treat honestly. For the values of y_2, however, condition (2.11) is met. At small values of y, i.e. y_1, a high-cost physician prefers to treat honestly if the share of high-cost physicians is small or medium and all low-cost physicians are honest. In that situation, too many patients with small problems are on their first visit and reject a fraud diagnosis with a high probability.

(c) $X_h \in (0,1)$. If all other high-cost physicians randomize between cheating and not cheating, a single high-cost physician randomizes too if and only if

$$X_h(y) = \frac{e - y(p_M - c_S^h)}{\delta(1-y)(p_M - c_S^h - e)} =: \tilde{X}_h(y). \tag{2.12}$$

The so-determined $\tilde{X}_h(y)$ lies below 1 if $\delta > \frac{e-y(p_M-c_S^h)}{\delta(1-y)(p_M-c_S^h-e)}$. If $X_h(y) > \tilde{X}_h(y)$, a high-cost physician prefers to overcharge and if $X_h(y) < \tilde{X}_h(y)$, it is her best response to treat honestly. Differentiation with respect to y generates

$$\frac{d\tilde{X}_h(y)}{dy} = -\frac{1}{\delta(1-y)^2} < 0. \tag{2.13}$$

That is, if more patients accept a fraudulent diagnosis on their first visit (i.e. we have a larger y), $\tilde{X}_h(y)$ can be lower to make the high-cost physician indifferent.

Then fewer patients with small problems on their second visit are needed for the physician to be indifferent. Notice that we reach $\tilde{X}_h(y) = 0$ at $y = \overline{y}^h$. Thus, for any $y > \overline{y}^h$, we have $X_h(y) > 0 > \tilde{X}_h(y)$ and a high-cost physician strictly prefers to overcharge as it also follows from our previous findings. Hence, when $\delta > \frac{e-y(p_M-c_S^h)}{\delta(1-y)(p_M-c_S^h-e)}$ and $y < \overline{y}^h$, the strategy $X_h \in (0,1)$ is a candidate for a symmetric best response.

Now consider $\frac{e-y_2(p_M-c_S^h)}{(1-y_2)(p_M-c_S^h-e)} \leq \delta \leq \frac{e-y_1(p_M-c_S^h)}{(1-y_1)(p_M-c_S^h-e)}$. We get $\tilde{X}_h(y_1) > 1$ and thus $X_h(y_1) < \tilde{X}_h(y_1)$. This means that for all values of y_1 a high-cost physician strictly prefers to treat honestly. However, we get $\tilde{X}_h(y_2) < 1$. Consequently, in this case for values of y between $\frac{e-\delta(p_M-c_S^h-e)}{p_M-c_S^h-\delta(p_M-c_S^h-e)} =: \tilde{y}^h$ and $\overline{y}^h$, the strategy $X_h \in (0,1)$ is a candidate for a symmetric best response.

2.5.2 Proof of Lemma 2.5

By the physician's individual best response in Lemma 2.2 and by Lemma 2.3, the low-cost physicians always diagnose honestly if the high-cost physicians are indifferent ($X_h \in (0,1)$) or always honest ($X_h = 0$). Therefore, in the following we analyze only the low-cost physicians' symmetric best response for the situation where all high-cost physicians cheat ($X_h = 1$). We derive the low-cost physicians' best response from the individual best response of a low-cost type.

We distinguish the same three cases of the patients' symmetric acceptance strategy, y, as in the proof of the high-cost physicians' symmetric best response:

1. $y = 1$. Substituting $y = 1$ into (2.3) and rearranging yields

$$e > p_M - c_S^h. \tag{2.14}$$

   This condition is fulfilled with certainty. Thus, the low-cost physicians always defraud all patients with a small problem if $y = 1$.

2. $y = 0$. Setting $y = 0$, $X = \delta + (1-\delta)X_l$ and rearranging (2.3) generates

$$e \left\{ \begin{array}{c} > \\ = \\ < \end{array} \right\} \frac{\delta + (1-\delta)X_l}{1 + \delta + (1-\delta)X_l} \left(p_M - c_S^h + \beta\right) - \beta. \tag{2.15}$$

   The best response of an individual low-cost physician depends on the other low-cost physicians' overcharging behavior. Therefore, we consider three situations with respect to the other low-cost physicians' defrauding behavior, X_l:

(a) $X_l = 0$. All other low-cost physicians treat all patients honestly. Considering $X_l = 0$ and rearranging (2.15) shows that an individual low-cost physician is honest as well if and only if

$$\delta < \frac{e+\beta}{p_M - c_S^h - e}. \tag{2.16}$$

If the share of cheating high-cost physicians is below $\frac{e+\beta}{p_M - c_S^h - e}$, a low-cost physician is honest if $X_l = 0$. Then there are several S-patients on their first visit so that being honest is more profitable than cheating for a low-cost physician at $y = 0$. When $\delta > \frac{e+\beta}{p_M - c_S^h - e}$, however, she deviates and cheats. If $\delta > \frac{e+\beta}{p_M - c_S^h - e}$, many patients with small problems are on their second visit and thus cheating is more profitable than recommending honestly. Note that $\frac{e+\beta}{p_M - c_S^h - e} < 1$ for $\beta < p_M - c_S^h - 2e$, where $p_M - c_S^h - 2e > 0$ due to the assumption $e < \frac{p_M - c_S^h}{2-y}$ (which simplifies to $e < \frac{p_M - c_S^h}{2}$ for $y = 0$). Hence, we have $\delta < 1 < \frac{e+\beta}{p_M - c_S^h - e}$ if $\beta > p_M - c_S^h - 2e$. Regarding β see the next case.

(b) $X_l = 1$. All other low-cost physicians always defraud patients with a small problem. According to (2.15) with $X_l = 1$ and rearranging, it is an individual low-cost physician's best response to defraud too if and only if

$$\beta < p_M - c_S^h - 2e. \tag{2.17}$$

When the cost advantage is sufficiently small, an individual low-cost physician still has incentives to cheat. Additionally, if all other physicians cheat, there are many patients with small problems on their second visit. Hence, if all other physicians defraud and $\beta < p_M - c_S^h - 2$, it is a low-cost physician's best response to cheat as well, despite $y = 0$. However, if $\beta > p_M - c_S^h - 2e$, a low-cost physician deviates and treats honestly as treating honestly is more profitable than overcharging in this case because of the larger cost advantage. Note that β is restricted from above by c_S^h and that we have $p_M - c_S^h - 2e < c_S^h$ for $e > \frac{p_M - 2c_S^h}{2}$. The condition $e > \frac{p_M - 2c_S^h}{2}$ is always satisfied since we suppose $\frac{p_M - c_S^h(2-y)}{2-y} < e < \frac{p_M - c_S^h}{2-y}$ (which simplifies to $\frac{p_M - 2c_S^h}{2} < e < \frac{p_M - c_S^h}{2}$ for $y = 0$). That is, within the range of our assumptions, $p_M - c_S^h - 2e < \beta < c_S^h$ is a possible situation.

(c) $X_l \in (0,1)$. All other low-cost physicians randomize between defrauding patients with a small problem and treating them honestly. A symmetric best response requires an individual low-cost physician to be indifferent as well. We rearrange (2.15) with an equal sign and observe that an individual low-cost physician is indifferent too if and only if

$$X_l = \frac{e + \beta - \delta(p_M - c_S^h - e)}{(1-\delta)(p_M - c_S^h - e)} =: \tilde{X}_l. \tag{2.18}$$

If $X_l > \tilde{X}_l$, a low-cost physician prefers to cheat, and if $X_l < \tilde{X}_l$, a low-cost physician prefers to treat honestly. We obtain $\tilde{X}_l > 0$ for $\delta < \frac{e+\beta}{p_M - c_S^h - e}$. Furthermore, we have $\tilde{X}_l < 1$ if $\beta < p_M - c_S^h - 2e$. Hence, for $\beta < p_M - c_S^h - 2e$ and $\delta < \frac{e+\beta}{p_M - c_S^h - e}$, the strategy $X_l \in (0,1)$ is a candidate for a best response. Given $\beta > p_M - c_S^h - 2e$ (which implies $\delta < \frac{e+\beta}{p_M - c_S^h - e}$) and thus $X_l < 1 < \tilde{X}_l$, an individual low-cost physician deviates and treats honestly. When we have $\beta < p_M - c_S^h - 2e$ and $\delta > \frac{e+\beta}{p_M - c_S^h - e}$, we obtain $X_l > 0 > \tilde{X}_l$ such that a low-cost physician strictly prefers to cheat. The reasons for these observations are analogous to the previous cases.

3. $y \in (0,1)$. Setting $X = \delta + (1-\delta)X_l$ and rearranging (2.3) with an equal sign yields

$$y(p_M - c_S^h + \beta) + (\delta + (1-\delta)X_l)(1-y)(p_M - c_S^h - e) - e - \beta = 0. \tag{2.19}$$

Again, we distinguish three settings regarding the other low-cost physicians' defrauding behavior:

(a) $X_l = 0$. By (2.19) with an inequality sign, an individual low-cost physician strictly prefers to diagnose her patients honestly if and only if

$$y < \frac{e + \beta - \delta(p_M - c_S^h - e)}{p_M - c_S^h + \beta - \delta(p_M - c_S^h - e)} =: \tilde{y}^l. \tag{2.20}$$

That is, for $y < \tilde{y}^l$, a low-cost physician treats honestly, and for $y > \tilde{y}^l$, she defrauds. When $y = \tilde{y}^l$, she is indifferent. Notice that $\tilde{y}^l > 0$ in case $\delta < \frac{e+\beta}{p_M - c_S^h - e}$. As a consequence, if $\delta > \frac{e+\beta}{p_M - c_S^h - e}$, we always get $y > \tilde{y}^l$.

(b) $X_l = 1$. We derive from (2.19) that if all other physicians defraud S-patients, it is an individual low-cost physician's best response to defraud too if and only if

$$y(p_M - c_S^h + \beta) + (1-y)(p_M - c_S^h - e) - e - \beta > 0. \tag{2.21}$$

This condition is fulfilled for $\beta < \frac{p_M - c_S^h - e(2-y)}{1-y}$. Note again that β is restricted from above by c_S^h and that $\frac{p_M - c_S^h - e(2-y)}{1-y} < c_S^h$ holds for $e > \frac{p_M - c_S^h(2-y)}{2-y}$. Since we assume $\frac{p_M - c_S^h(2-y)}{2-y} < e < \frac{p_M - c_S^h}{2-y}$, the condition $\beta > \frac{p_M - c_S^h - e(2-y)}{1-y}$ is an option in our framework.

(c) $X_l \in (0,1)$. In case all other low-cost physicians randomize between cheating and not cheating, an individual low-cost physician is indifferent between defrauding and treating honestly if and only if

$$X_l(y) = \frac{e + \beta - y(p_M - c_S^h + \beta)}{(1-\delta)(1-y)(p_M - c_S^h - e)} - \frac{\delta}{1-\delta} =: \tilde{X}_l(y). \tag{2.22}$$

When $X_l(y) > \tilde{X}_l(y)$, a low-cost physician cheats, and when $X_l(y) < \tilde{X}_l(y)$, she diagnoses honestly in any case. We get $\tilde{X}_l(y) < 1$ when $\beta < \frac{p_M - c_S^h - e(2-y)}{1-y}$. Hence, if $\beta > \frac{p_M - c_S^h - e(2-y)}{1-y}$, we have $X_l(y) < 1 < \tilde{X}_l(y)$ and then a low-cost physician treats honestly. Furthermore, differentiating with respect to y shows

$$\frac{d\tilde{X}_l(y)}{dy} = -\frac{1}{(1-\delta)(1-y)^2} < 0. \tag{2.23}$$

Consequently, when more patients accept a major diagnosis on their first visit, a low-cost physician would be indifferent at a reduced fraud level for the same reasoning as for the high-cost physicians. The indifference fraud level $\tilde{X}_l(y)$ reaches zero at $y = \tilde{y}^l$. Thereby, for $y > \tilde{y}^l$ and thus $X_l(y) > 0 > \tilde{X}_l(y)$, a low-cost physician cheats, as also indicated by our previous findings. Hence, when $\beta < \frac{p_M - c_S^h - e(2-y)}{1-y}$ and $y < \tilde{y}^l$ (which requires $\delta < \frac{e+\beta}{p_M - c_S^h - e}$), the strategy $X_l \in (0,1)$ is a candidate for a symmetric best response.

2.5.3 Proof of Lemma 2.6

Given a pair (X, y) such that both types of physicians diagnose honestly, the according level of fraud is $X = 0$. When $X = 0$, the best response of a high-cost physician determines whether the physicians' joint best response is mutually compatible since the low-cost physicians are always honest in this setting, due to their weaker fraud incentives compared to the high-cost physicians.

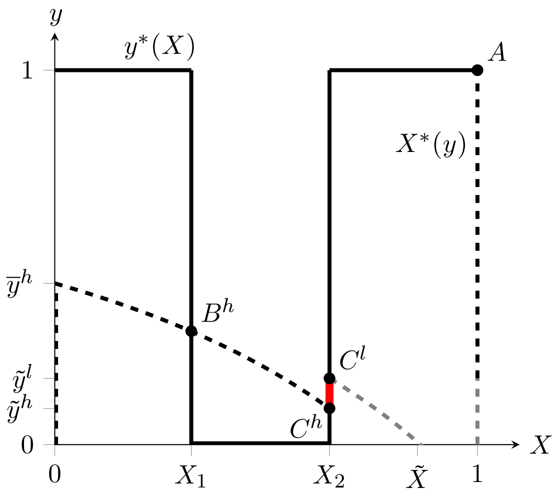
For a pair (X, y) such that the high-cost types are indifferent and the low-cost physicians are honest, the corresponding level of fraud is given by $X = \frac{e - y(p_M - c_S^h)}{(1-y)(p_M - c_S^h - e)}$. This fraud level is bounded from above by $min\{\overline{X}, \delta\}$. The mutual compatibility of the physicians' joint best response is given by the best response of a high-cost physician. This is because there are no fraud incentives for the low-cost types in this case either.

With a pair (X, y), where the high-cost types cheat and the low-cost types are honest, the only consistent market level of fraud is $X = \delta$. A mutually compatible joint best response is given by the convex combination $\lambda \tilde{y}^l + (1-\lambda)\tilde{y}^h > 0$, where $\lambda \in [0,1]$. This is because the low-cost physicians' honesty is ensured by $y < \tilde{y}^l$ and the high-cost physicians' dishonesty by $y > \tilde{y}^h$. However, the convex combination exists only for $\delta < \frac{e}{p_M - c_S^h - e}$. For

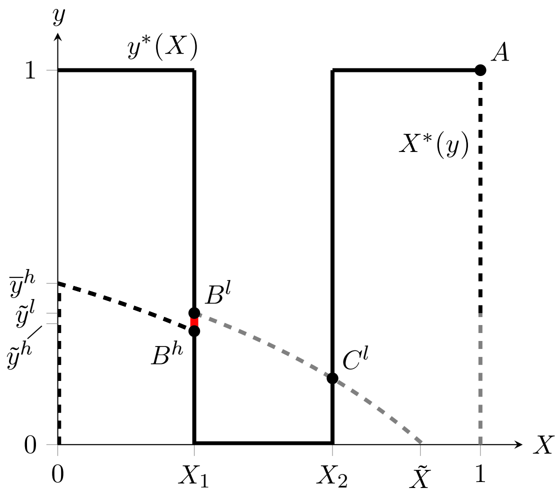
$\frac{e}{p_M - c_S^h - e} < \delta < \frac{e+\beta}{p_M - c_S^h - e}$, $y < \tilde{y}^l$ must hold to ensure that the case of cheating high-cost physicians and honest low-cost physicians is mutually compatible. This is because the high-cost physicians could cheat for any $y \in [0, 1]$ if $\frac{e}{p_M - c_S^h - e} < \delta < \frac{e+\beta}{p_M - c_S^h - e}$.
For a pair (X, y) such that all high-cost physicians cheat and all low-cost physicians are indifferent, the corresponding market level of fraud is given by $X = \frac{e+\beta-y(p_M - c_S^h + \beta)}{(1-y)(p_M - c_S^h - e)}$. This fraud level is bounded from below by δ due to the high-cost physicians being dishonest with certainty. As a consequence of their lower fraud incentives, the mutually compatible joint best response is here given by the low-cost physicians' best response.
Given a pair (X, y) such that both types of physicians cheat, the according fraud level is $X = 1$. This fraud level corresponds to the best response of a low-cost type because the high-cost types always defraud when the low-cost types defraud.

2.5.4 Further Equilibrium Cases

Figure 2.5 displays the two cases where a continuum of equilibria occurs (depicted by a red bold line). The continuum is described by $\{\lambda C^l + (1-\lambda)C^h | \lambda \in [0, 1]\}$ when $\delta = X_2$ (Figure 2.5a) and by $\{\lambda B^l + (1-\lambda)B^h | \lambda \in [0, 1]\}$ when $\delta = X_1$ (Figure 2.5b).



(a) $\delta = X_2$



(b) $\delta = X_1$

Figure 2.5: Equilibrium settings with continua of equilibria

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