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# Credence Goods and Fraudulent Experts

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## Abstract

This paper is about a market for credence goods. With a credence good consumers are never sure about the extent of the good they actually need. Therefore, sellers act as experts determining the customers' requirements. This information asymmetry between buyers and sellers obviously creates strong incentives for sellers to cheat on services. We analyze whether the market mechanism may induce non-fraudulent seller behavior. From the observation of market data such as prices, market shares etc., consumers can infer the sellers' incentives. We show that market equilibria resulting in non-fraudulent behavior do indeed exist.

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## 1. Introduction

This paper is about expert services. Expert services are provided by medical doctors and lawyers as well as by less glamorous repair professions like auto mechanics and appliance service-persons. All these professions have in common that typically the seller not only provides the repair services; at the same time, the seller acts as the expert who determines how much treatment is necessary because the customer is unfamiliar with the intricacies and peculiarities of the good in question.

Aggravating this special feature is the fact that even ex post consumers can hardly determine the extent of the service that was required ex ante. It is often difficult, if not impossible, to find out whether repairs were really needed or whether necessary treatments were not performed. Brake shoes changed prematurely work in the same way as if the shoes replaced had been really faulty; so does the patient with his appendix removed (un-)necessarily. In contrast, the wisdom tooth may hurt even when it was in perfect condition at the time of the last check-up; toothache need therefore not prove that necessary treatment was not carried out. Since from ex post observations the buyer can never be certain of the quality of the services he has purchased, such services have been termed credence goods (Darby and Karni (1973)).

The information asymmetry between buyer and seller obviously creates strong incentives for opportunistic seller behavior. On the one hand, if there is plenty of money in repair, sellers may recommend treatments that are not necessary. On the other hand, they may not perform an urgently needed repair if other activities are more profitable. The chances of consumers finding out about such fraudulent behavior are typically slim. Since the problem is a common one and evidence on seller honesty is difficult to obtain, the media enjoy publicizing those anecdotes about fraudulent experts whose actions are covered up.[1)]

Apparently, there is a need for mechanisms to discipline fraudulent experts. Perhaps the simplest mechanism ensuring honest services is the separation of diagnosis and treatment. Unless there is collusion, the diagnosing expert has no incentive to recommend unnecessary treatments and the repairing expert may only fix what has been diagnosed by her colleague. An example of this simple yet effective mechanism is the often encountered separation of the prescription and the preparation of drugs.

This 'separation' mechanism, however, fails to do a good job when it is cheaper to provide diagnosis and repair jointly rather than separately. It is, for example, cheaper to repair any damage while the transmission or belly is open for diagnosis than to put everything back together and repeat the process elsewhere for the actual repair. Apparently, such economies of scope between diagnosis and repair also make the related mechanism of consulting several experts unattractive.

In this paper we want to analyze whether the market may solve the fraudulent expert problem when there are profound economies of scope between diagnosis and treatment. In our setup repair is possible only after diagnosis. A customer choosing the services of a second expert, therefore, automatically incurs the cost of a further diagnosis which makes the 'separation' as well as the 'second opinion' mechanisms unattractive. From the observation of market data such as quoted prices and market shares consumers attempt to infer the sellers' incentives to provide honest/fraudulent services which are assumed to be verifiable. We show that market equilibria inducing non-fraudulent behavior do indeed exist.

We consider experts who are capacity constrained: an active expert may have to ration her clientele due to insufficient capacity or she may also end up with idle capacity. Experts charge separate prices for diagnosis and repair. Competition is thus of the Bertrand-Edgeworth type.

First we analyze how an expert's incentives depend on the interplay of prices, capacity, and size of her clientele. If, say, the expert does not have enough customers, she may carry out unnecessary repairs to utilize her otherwise idle capacity; with too many customers she may repair inefficiently little if diagnosis is more profitable than treatment. We show that if the experts charge what we call equal compensation prices, they are indifferent between diagnosis and repair given enough customers to allow them to work at full capacity: with these prices diagnosis and repair generate the same profit at the margin. Therefore, experts are honest with equal compensation prices given a clientele permitting them to work at full capacity. If the expert does not have enough customers, she over-treats to make some money out of her otherwise unused capacity. This incentive to repair too much disappears if and only if there is no money in repair.

In a second step we determine the equilibrium prices. These prices depend crucially on the number of active experts. If demand exceeds the active experts' capacity, experts charge those equal compensation prices that make consumers indifferent between buying and not buying the experts' services. With these reservation prices experts are honest and appropriate the entire surplus. In contrast, if capacity exceeds demand, Bertrand competition drives prices down to marginal costs of zero. Since at these marginal cost prices there is no money in repair, experts are honest even with idle capacity. Here consumers appropriate the entire surplus.

Finally, we analyze the experts' entry decision. We first confine our attention to symmetric strategies. Since there are more experts than necessary to serve the whole market with honest behavior, the experts' entry strategies are mixed. Free entry in the expertise business drives expected profits down to zero. Accordingly, experts choose the probability of entry so that they all make zero profits on average. Moreover, we show that an asymmetric equilibrium exists in which experts are honest and appropriate the entire surplus.

The extent of the theoretical literature on fraudulent experts is fairly small. In a classic article Darby and Karni (1973) discuss how reputation, market conditions, and technological factors affect the amount of fraud. Their paper relies heavily on verbal arguments and anecdotes. Yet it contains some of the ideas we formalize in the paper at hand.

Pitchik and Schotter (1987) describe a mixed-strategy equilibrium in an expert-customer game. The expert randomizes between either reporting truthfully or not; the customer randomizes between acceptance and rejection of a treatment recommendation.

Demski and Sappington (1987) focus on the problem of inducing an expert to acquire a costly expertise. Whereas in our model diagnosis is necessary prior to repair, 'blind treatment' is possible in Demski and Sappington who assume repair to be costless. In this setup they study optimal contracts between a principal and an expert (agent).

Wolinsky (1993) examines customer search for multiple opinions and reputation considerations. In his specialization equilibrium some experts exclusively provide diagnosis while the other experts engage in either activity. Consumers first visit a 'diagnosis-only' expert. If she recommends treatment, consumers visit a 'two-activity' expert for a second diagnosis and the actual repair. Our analysis differs from Wolinsky's in several respects. In particular, while our equilibria result in efficient diagnosis and repair, in Wolinsky's equilibria there is too much diagnosis.

Taylor (1995) considers experts who, unlike our experts, incur no cost for unnecessary treatments. Unnecessary repairs are thus not inefficient in his setup. His experts never diagnose a product as healthy; moreover, ex post contracting, free diagnostic checks, consumer procrastination in obtaining checkups, and long-term maintenance agreements may occur in Taylor's equilibria.

Closest to this analysis is our paper (Emons (1995)). While the paper at hand is about competitive experts, there we consider a credence good monopolist. The monopolist's capacity is determined endogenously. From the observation of i) capacity and prices or ii) just prices consumers attempt to infer the quality of the seller's services. Moreover, we distinguish between the cases of observable and unobservable expert diagnosis and repair services. We show that for three out of the four possible constellations the monopolist always chooses non-fraudulent behavior. Only when capacity and services are non-observable does no trade take place. The two papers are thus related in their basic result: if consumers rationally process ex ante information, the market mechanism can solve the fraudulent expert problem.[2)]

The remainder of the paper is organized as follows. In the next section we describe the model. In section 3 we describe the experts' repair policy. In the subsequent section we derive the pricing strategy. In section 5 we describe the entry decision. Section 6 contains a discussion of our results. Section 7 concludes the paper. Proofs are relegated to the Appendix.

## 2. The Model

We consider a durable good endowed with a stock of services. When a certain amount of services is left over, the product is up for diagnosis and potential repair. We normalize this remaining capacity to 1 monetary unit. During its remaining life, our durable good is of the 'one-hoss shay' type, i.e., either it makes available total remaining services 1 or it delivers services 0.

When the product is up for diagnosis, it can be in good or in bad shape. If the product is in good shape, it makes available services 1 with probability $q_h \in (0, 1)$; when the product is in bad shape, the corresponding probability is $q_\ell$ with $0 < q_\ell < q_h$. Accordingly, in either condition the product may either work or fail. Yet when it is in good shape, the probability of working is higher. Let $p$ denote the probability that the product is in bad and $(1 - p)$ the probability of the product being in good shape. The consumer does not know which of the two conditions his product is in.

Experts, however, are able to detect the product's condition. By diagnosing the product, an expert finds out whether it is in good or in bad shape. When the product is in bad shape the expert can fix it so that it is in good shape afterwards. Let $d > 0$ be the total resource cost of diagnosing a product; the total resource cost of a repair is $r > 0$.

The timing of the production decisions, however, is such that these costs are not experienced as genuine marginal costs. An expert has to make a prior decision on entry. The expert has $L$ units of time (say, hours) available. If she does not enter the market for expertise, she can work $L$ hours in an alternative activity. If she does enter the expert business, she allocates her $L$ units of time to diagnosis and repair; $d$ is the time an expert needs per diagnosis and $r$ the time per repair. An expert's time cost, however, is sunk. Once she has entered the market, she can only use her time for diagnosis and repair; she can no longer work in the alternative job.

The experts' reservation wage is normalized to 1. Accordingly, $L$ is the sunk cost of becoming active; $d$ and $r$ measure the minimum average costs of diagnosis and repair if, say, the expert performs either activity exclusively. Note that marginal costs are different from average costs. An active expert has a fixed capacity the cost of which is sunk. Therefore, her marginal costs are 0 except for the capacity margin where marginal costs are "$+\infty$". When, in the following, we talk about minimum average costs we mean $d$ and $r$.

There is a continuum of identical consumers with total measure 1.[3)] Consumers are risk neutral and care only about monetary flows. Accordingly, given that we have normalized the product's remaining capacity to 1 monetary unit, without diagnosis and repair a consumer's expected utility is $\bar{U} = (1-p)q_h + pq_\ell$. With (honest) diagnosis and repair priced at minimum average costs the consumer's expected utility amounts to $q_h - d - pr$. The consumer incurs the cost of diagnosis in any case. With probability $p$ the product is in bad shape and needs treatment. In return, the consumer has a product that is in good shape for sure.

It is efficient to check the product and fix it if necessary, meaning $q_h - d - pr > \bar{U}$ or $p(q_h - q_\ell) > d + pr$. Fixing a bad product increases the consumer's utility by $(q_h - q_\ell)$. With probability $p$ the product is in bad shape. Accordingly, the expected benefit from diagnosing and repairing the product is $p(q_h - q_\ell)$. The surplus the experts' services may generate is, therefore, $p(q_h - q_\ell) - (d + pr)$. For notational purposes we define the ratio of aggregate benefits to aggregate costs $w := p(q_h - q_\ell)/(d + pr) > 1$.

There are $I$ identical experts indexed by $i = 1, \ldots, I$. An expert either enters the market with capacity $L$ or she does not enter at all; we call the former an active and the latter an inactive expert. We assume that repair is possible only after diagnosis.[4)] Given non-fraudulent behavior, an expert's capacity $L$ in units of time thus translates into the capacity $L/(d + pr)$ in terms of customers.

Experts are not 'too large' relative to the market; more specifically, an expert cannot serve more than half of the market given honest behavior. Furthermore, to avoid integer problems let $L/(d + pr) := 1/k \in \mathbb{Q}$. Accordingly, $k$ experts, $k \geq 2, k \in \mathbb{N}$, are sufficient to serve the entire market with honest services. Moreover, to ensure competitive behavior there are more experts than necessary to serve the entire market, i.e., $k < I$. Indeed, to have a simple closed form solution for an expert's entry decision, we will assume that $I = k + 1$.[5)]

Let us now describe how experts may defraud consumers. After diagnosis the expert knows which condition the product is in. When the product is in bad shape, she can repair it, i.e., turn it into good shape. Yet she can also 'repair' a good product; in this case the expert unnecessarily works $r$ units of time on the product — leaving it at least in good shape. Alternatively, when the product is in good condition, the expert can recommend not to fix it. Nevertheless, she can make the same recommendation when the product is in bad shape. Ex post the consumer has no way of finding out whether his product was repaired unnecessarily or whether it needed treatment that was not provided. The expert's services thus constitute 'credence' goods as distinct from search and experience goods — from ex post observations the consumer can never be certain of the quality of the services he has purchased. The only possibility for the consumer not to be defrauded is to infer the expert's incentives to be honest from ex ante observable variables such as the quoted prices and market shares.[6)]

Note that we assume diagnosis and repair to be verifiable. This assumption is appropriate for, say, dentists whose customers, willy-nilly, suffer any (un-)necessary drilling. It is not appropriate for, e.g., a customer taking his car to the shop in the morning and picking it up in the evening without being able to tell whether the mechanic has actually worked on the vehicle. Here the expert has yet another possibility to defraud her customers. She can claim to have fixed the car without having touched it, thus collecting repair fees from an unlimited number of customers. This related problem is dealt with in Emons (1995).

An expert picks prices $D$ and $R$ that she charges for diagnosis and repair. Moreover, she chooses a repair policy conditional on the product's condition. We identify this policy by the probability of repair. Let $\alpha$ denote the probability of repair given that the product is in good shape and $\beta$ the probability of treatment if the product is in bad shape. These two conditional probabilities determine the unconditional ex ante probability of repair $\gamma = (1-p)\alpha + p\beta$ which is quite useful for later purposes.

With this notation we may distinguish three scenarios. If $\alpha = 0,\ \beta = 1$, and thus $\gamma = p$ we talk of *efficient repair.* The expert fixes all bad and no good products; thereafter a product is certainly in good shape. A consumer's expected utility with this honest repair policy is $q_h - D - pR$.

If $\alpha > 0,\ \beta = 1$, and thus $\gamma = (1-p)\alpha + p$ we talk of *too much repair.* The expert not only fixes all bad but also good products. With this fraudulent repair policy a consumer's expected utility amounts to $q_h - D - \gamma R$. Obviously, the consumer prefers efficient repair to too much repair.

Finally, if $\alpha = 0,\ \beta < 1$, and thus $\gamma = \beta p$ we talk of *too little repair.* The expert fixes no good and not all bad products. With this deceitful repair policy a product may be in bad shape and the consumer's expected utility is $(1-p+\gamma)q_h + (p-\gamma)q_\ell - D - \gamma R$. The consumer prefers efficient to too little repair if $(q_h - q_\ell) \geq R$ which must be satisfied since $(q_h - q_\ell)$ is the consumer's reservation utility for repair if the product is in bad shape. If the expert is indifferent between honest and fraudulent behavior, she behaves honestly. Note that the expert's repair policy defines her capacity in terms of customers $L/(d+\gamma r)$.

Consumers consult an expert if and only if the expected utility of being served by her exceeds $\bar{U}$. All consumers first visit the expert offering the most favorable terms If, given her repair policy, this most favored expert has insufficient capacity, she rations her customers randomly. The rationed consumers then go to the 'second-best' expert etc. If there is no other active expert, or the remaining experts offer bad deals, the rationed consumer ends up with no service and, accordingly, has utility $\bar{U}$. If the offers of several experts are equally the best, the consumer gives equal weight to all of them.

This consumers' search strategy together with the experts' rationing policy gives rise to a distribution of consumers over experts. Let $\eta_i(\cdot)$ denote the fraction of consumers ending up with expert $i, i = 1, \ldots, I$. Since consumers have total mass 1, $\eta_i$ also measures expert $i$'s clientele. If $\eta_i \leq L/(d+\gamma_i r)$, expert $i$ has enough capacity to treat her entire clientele. Let $\zeta_i$ denote the probability of being served by expert $i$ so that, in this case, $\zeta_i = 1$. If $\eta_i > L/(d+\gamma_i r)$, expert $i$ has more customers than she can handle with her repair policy. Therefore, she has to ration her customers randomly and $\zeta_i = L/(d+\gamma_i r)\eta_i$. The number of customers treated by the expert is thus $\min\{\eta_i; L/(d+\gamma_i r)\}$; her expected profit amounts to $\min\{\eta_i; L/(d+\gamma_i r)\}(D_i + \gamma_i R_i) - L$ if she is active and zero otherwise.

Let us now turn to the formulation of the game which we have set up as a four stage game. In the first stage of the game experts decide about entry; more specifically, expert $i, i = 1, \ldots, I$, picks the probability of entry $\sigma_i \in [0,1]$. In the second stage those $j$ experts who are in the business choose prices $(D_i, R_i),\ i = 1, \ldots, j,\ j = 1, \ldots, I$. In the third stage consumers observe the quoted prices $(D_i, R_i)_{i=1}^{j}$. Then consumers start their sequential search. Consumers' search along with the experts' rationing procedure determine $\eta_i \in [0,1],\ i = 0, \ldots, j, \sum_{i=0}^{j} \eta_i = 1$, where $\eta_0$ denotes the fraction of consumers going to no expert. In the fourth stage expert $i$ chooses her repair policy $\alpha_i(D_i, R_i, \eta_i)$ and $\beta_i(D_i, R_i, \eta_i),\ i = 1, \ldots, j$.[7)]

In stage three consumers have beliefs $(\hat{\alpha}_i, \hat{\beta}_i)_{i=1}^{j}$ about the experts' stage four repair policies. Consumers evaluate the expected utility $U(D_i, R_i, \hat{\alpha}_i, \hat{\beta}_i, \zeta_i)$ with each expert $i$, $i = 1, \ldots, j$, according to these beliefs. Each consumer chooses his search strategy so as to maximize his expected utility; if a consumer is indifferent between consulting and not consulting an expert, he opts for a consultation. Experts choose prices and repair policies so as to maximize expected profits. We first confine our attention to symmetric strategies for all agents; in section 6 we also look at asymmetric strategies.

We focus on subgame perfect equilibria. This means, in particular, that each decision maker acts in a sequentially rational fashion, following a strategy from each point forward that maximizes the expected payoff given the current information and beliefs. In our setup this implies that the experts' repair policies are indeed optimal once consumers arrive. In equilibrium the consumers' beliefs are borne out: what consumers expect is what experts actually choose to do.

## 3. The Repair Policy

We solve the game by backwards induction. Accordingly, we begin the analysis by studying the experts' diagnosis and repair incentives in stage four which are embedded in the functions $\alpha_i(\cdot)$ and $\beta_i(\cdot)$. Recall that an expert enters the market with a capacity of $L$ units of time having a sunk cost $L$. In terms of customers the expert has capacity $L/(d+pr)$ given honest behavior. Apparently, expert $i$'s behavior depends on the size of her clientele $\eta_i$ relative to her capacity $L/(d+pr)$. According to whether $\eta_i \lesseqgtr L/(d+pr)$ we will say that expert $i$ has too many/enough/not enough customers given non-fraudulent behavior. If, say, the expert does not have enough customers, she may start 'repairing' good products to utilize her otherwise idle capacities. If she has too many customers, she may, e.g., be tempted not to fix all bad products given that diagnosis is more profitable than repair.

The last example indicates that the expert's incentives also depend on the relative profitability of diagnosis to repair which, in turn, is determined by her prices $D_i$ and $R_i$. If the expert has too many customers, the only constraint she faces (at the margin) is her precious time. To maximize profits, she compares the profit per hour repair $(R_i - r)/r$ with the profit per hour diagnosis $(D_i - d)/d$. If the former exceeds the latter she will repair too much and vice versa if diagnosis is more profitable than treatment. We specify these ideas more precisely in the following Lemma.

**Lemma 1:**

*i) If $\eta_i > L/(d+pr)$, expert $i$ is honest if and only if $R_i = rD_i/d$;*
*ii) if $\eta_i = L/(d+pr)$, expert $i$ is honest if and only if $R_i \leq rD_i/d$;*
*iii) if $\eta_i < L/(d+pr)$, the expert is honest if and only if $R_i = 0,\ i = 1, \ldots, j$.*

< *insert Figure 1 about here* >

The message of Lemma 1 can be seen in Figure 1. Consider the line $R_i = rD_i/d$ along which $(R_i - r)/r = (D_i - d)/d$. Accordingly, on this equal compensation line the expert is indifferent between diagnosis and treatment so that with too many customers she opts for efficient repair.[8)] In region $(I)$ where $R_i > rD_i/d$ the expert prefers repair to diagnosis. Whatever the number of customers, she will 'fix' anything she diagnoses, i.e., repair too much. In region $(II)$ in which $R_i < rD_i/d$ the expert prefers diagnosis to repair so that she wishes to increase the number of diagnoses at the expense of repairs. With enough customers, however, she cannot diagnose more products; she repairs efficiently to make some money out of her otherwise unused capacity. Along the $D_i$-axis the expert has proper incentives if she does not have enough customers. She does not repair too much to utilize her idle capacity because there is no money in treatment.[9)]

Subgame perfection implies that the consumers' beliefs $(\hat{\alpha}_i, \hat{\beta}_i)_{i=1}^{j}$ reflect the experts' incentive structure we have just derived. Note that it is possible to pin down the experts' incentives even further once we incorporate the entire list of prices $(D_i, R_i)_{i=1}^{j}$. We will do this in the next section. The most important aspects of the experts' incentives, however, are summarized by Lemma 1.

## 4. The Pricing Strategy

Let us now determine the experts' stage two pricing policy together with the consumers' stage three search strategy. The pricing strategy depends crucially on the number of active experts. If, on the one hand, the number of experts and thus capacity is less or equal to total demand, the experts charge the consumers' reservation prices; if, on the other hand, capacity exceeds demand, experts charge marginal cost prices. In both scenarios, however, consumers obtain honest services.

**Lemma 2:** *If $j = 1, \ldots, k$ experts are active, expert $i$ charges $(D_i, R_i) = (dw, rw)$, $i = 1, \ldots, j$; consumers get no surplus and all experts work at full capacity. If $(k+1)$ experts are active, expert $i$ charges $(D_i, R_i) = (0, 0)$, $i = 1, \ldots, k+1$; consumers get the entire surplus and all experts have idle capacity. These prices are unique for $j = 1, \ldots, k-1$ and for $k+1$ experts. If $k$ experts are active, all prices $D_i \in [dw, p(q_h - q_\ell)]$ and $R_i = q_h - q_\ell - D_i/p$, $i = 1, \ldots, k$ are Nash equilibria of the price game.*

This result may be explained as follows. Consider first the cases where there are $k$ or less than $k$ active experts so that with non-fraudulent behavior total capacity is less or equal to total demand. Experts are thus the short and consumers the long side of the market. This constellation gives experts the power to charge the reservation prices.

A consumer is happiest about the expert's services when he gets for sure a product being in good shape; then the consumer has the maximum willingness-to-pay of $p(q_h - q_\ell)$ for the expert's services. The consumer certainly has a good product if the expert repairs efficiently or if she repairs too much. The consumer's overall willingness-to-pay does not increase if the expert raises repair above the efficient level. Yet, if she repairs too much, she needs more of her precious time than with efficient repair, without making more money. Accordingly, the expert maximizes her profits per consumer by non-fraudulent repair. The maximum prices the consumer is willing to pay for honest services, i.e., the prices generating the reservation utility $\bar{U}$ are given by the indifference curve $R_i = q_h - q_\ell - D_i/p$; see Figure 1. With these prices and honest repair, the consumer tries to get hold of the expert's services.

Next, note that if the number of active experts does not exceed $k$, all active experts have more than, or exactly the number of customers, that they can handle with honest behavior. From Lemma 1 we know that with too many customers the expert is honest if and only if she charges prices on the equal compensation line $R_i = rD_i/d$, see Figure 1. Consequently, by charging the prices $(dw, rw)$, consumers know they are treated honestly and the expert appropriates all the surplus per consumer.

Finally, note that no expert has an incentive to deviate. All experts work at full capacity. A consumer who is served is as well off as a consumer who is rationed. If an expert offers more attractive terms, say lower prices on the equal compensation line, all customers try to get her services. However, she cannot serve more than $L/(d + pr)$ customers so that such a customer-friendly deviation lowers her profits. If she offers prices above the consumers' reservation prices, she loses all her customers and makes a loss $L$.

Now consider the case with $(k + 1)$ experts. In this constellation market capacity with honest behavior exceeds market demand. Here experts are the long side of the market and charge marginal cost prices. First note that with marginal cost prices $(0, 0)$ experts are honest whatever the number of customers. With not enough customers, experts are honest because there is no money in repair; with too many customers experts are honest because marginal cost prices are on the equal compensation line. Accordingly, consumers get honest services and end up with the utility $p(q_h - q_\ell)$.

If an expert unilaterally increases her prices, the utility of her customers obviously falls below $p(q_h - q_\ell)$. Accordingly, all $1/(k + 1)$ customers of the deviating expert will try to consult one of the non-deviating experts. Since the $k$ non-deviating experts have idle capacity of $1/(k+1)$, they can provide honest services to all of the deviating expert's customers. Since with prices $(0, 0)$ the non-deviating experts have proper incentives, all customers of the deviating expert are therefore served honestly by the non-deviating experts. Consequently, with any positive prices an expert loses all her customers to her colleagues, making such a price increase unattractive.

## 5. The Entry Decision and the Equilibrium of the Entire Game

Let us finally analyze the experts' entry decision in the first stage of the game. The experts' entry strategy is strictly mixed. The probability of entry is such that all experts make expected zero profits.

**Lemma 3:** *In the first stage of the game expert $i$ enters with probability $\sigma_i := \sigma = \sqrt[k]{1 - 1/w},\ i = 1, \ldots, k+1$.*

This result is easily explained. Obviously, experts cannot play pure strategies in a symmetric equilibrium. If all experts stay out of the market, unilaterally entering is highly profitable; conversely, if all experts enter, each of them makes a loss which can be avoided by staying out of the business. Accordingly, experts will randomize whether or not to enter. If, say, all experts but the first enter with probability $\sigma$, expert 1 makes expected zero profits if she enters, or stays out, or chooses any mixture of the two pure strategies. Consequently, it is also an optimal strategy for expert 1 to enter with probability $\sigma$ so that all experts end up with expected zero profits.

We are now in the position to describe the symmetric equilibrium of the entire game which has the following features: Experts randomize their entry decision. If experts are the short side of the market, they charge reservation prices; if they are the long side, they charge marginal cost prices. Consumers buy in both scenarios and get honest services.

**Proposition 1:** *In a symmetric subgame perfect equilibrium the experts' stage 1 entry decision is given by Lemma 3. Their stage 2 pricing strategy is summarized by Lemma 2. Consumers' stage 3 beliefs about the repair policy and the experts' actual repair policy are as described in Lemma 1.*

## 6. Discussion

Let us start with the welfare analysis. In our equilibrium consumers get honest service and experts make expected zero profits. All the expected surplus that is generated goes to consumers. In contrast, any situation with fraud is inefficient: there is either over- or under-treatment. Since experts have the correct incentives, we may thus conclude that the market mechanism solves the fraudulent expert problem.

Notice, however, that our equilibrium leads to inefficient entry. Recall that $k$ experts are sufficient to serve the entire market with honest services. Accordingly, efficiency requires $k$ experts to be active. Yet in our equilibrium any number of experts between 0 and $(k + 1)$ will be active with positive probability; our equilibrium thus results in inefficient capacity levels. We will return to this point when we next discuss the issue of uniqueness.

Our equilibrium is not unique. First, the price game with $k$ experts has a continuum of prices supporting non-fraudulent behavior; see Lemma 2. Second and more important, the entry subgame has asymmetric equilibria: $k$ experts enter and one expert stays out of the business.

**Lemma 4:** *In the first stage of the game some expert $j$ chooses $\sigma_j = 0$, $j = 1, \ldots, k+1$, while the remaining experts enter with probability $\sigma_i = 1$, $i = 1, \ldots, k+1$, $i \neq j$.*

Obviously, these entry decisions give rise to asymmetric equilibria for the entire game.

**Proposition 2:** *The entry decisions given by Lemma 4 together with the pricing and repair policies of Lemmata 2 and 1 form subgame perfect equilibria of the entire game.*

In these asymmetric equilibria the efficient number of experts is active. The $k$ active experts charge prices $(dw, rw)$, are honest, and appropriate the entire surplus. The inactive expert does not enter because this inevitably leads to excess capacity and marginal cost prices; she would make a loss which she can avoid by staying out of the business.

While these asymmetric equilibria may, at first glance, appear more appealing than our symmetric equilibrium, there is a snag to them. Recall that we have assumed that total demand is an integer multiple of the individual capacity. We have made the assumption for the following reason. If there is excess capacity, there is *at least* one expert too many in the market. If in such a situation an expert raises her prices, she immediately loses her entire clientele; nobody comes back because the non-deviating experts have enough spare capacity. Since residual demand is zero, no expert deviates from marginal cost prices.

If the integer assumption fails to be satisfied, if say $k = 7.5$, the price game with 8 experts possesses no equilibrium in pure strategies. Reservation prices cannot be an equilibrium because all experts have idle capacity and undercutting pays off. Marginal cost prices also cannot be an equilibrium. If an expert slightly raises her prices, she retains the residual demand of .5 which cannot be satisfied by her colleagues. The integer assumption thus saves us from deriving the mixed strategy equilibrium for this particular price game which has some nasty features.

If there are sufficiently many experts, in our symmetric equilibrium the probability of hitting this problematic number of experts is small so that what exactly happens in this price game is of minor importance. In the asymmetric entry equilibrium, the problematic number of experts always comes up so that the analysis of that situation is crucial to the equilibrium. Moreover, given that we have assumed free entry and Bertrand competition, we are happier with the zero profit equilibrium. Nevertheless, the asymmetric equilibrium is efficient while the symmetric one is not. Perhaps the symmetric equilibrium is better suited to capture the 'short run' situation while the asymmetric equilibrium describes the 'long run' situation. Furthermore, a regulator can try to implement the asymmetric equilibrium by some kind of licensing.

Let us make a last remark on the robustness of our results. Our findings are corroborated by our related paper (Emons (1995)). Since that paper is about credence goods monopolists, we do not encounter strategic competition considerations. This simplifying aspect allow us to extend the analysis in other directions. We endogenize the capacity choice and also analyze what happens if capacity is unobservable; moreover, we allow for non-observable and thus non-verifiable expert services. Due to the simple structure of the model, we can completely characterize the set of equilibria, all but one of which share the following features: The monopolist serves the entire market with honest services and appropriates the entire surplus. It is only when capacity *and* services are non-observable that no trade takes place. Accordingly, the message of the two papers is in the same spirit. If consumers rationally process ex ante information about market conditions, the market mechanism can solve the fraudulent expert problem. Experts are honest to maximize the consumers' surplus. In the monopoly case non-fraudulent services generate the highest profit for the monopolist; in the competitive setup honesty is necessary in order to survive.

## 7. Conclusions

We have analyzed credence goods which are provided by experts. Since consumers can never be certain of the quality of the sellers' services, experts have strong incentives to cheat. We have shown that if consumers rationally process all the information about market conditions, they can infer the sellers' incentives and the market may indeed solve the fraudulent expert problem.

Our results permit to discriminate more clearly between those situations in which market institutions may solve the fraudulent expert problem and those circumstances where the market fails so that we need other mechanisms to discipline sellers. In reality we encounter both these cases. For a lot of skilled trades, such as carpentry, plumbing, or bicycle repair, the market mechanism seems to do a fairly good job just as our model predicts. In other professions, as the examples in the Introduction suggest, there is fraud so that other mechanisms are called for to induce honest services. Since expert services are often subject to licensing and regulation, a more thorough understanding of these markets will be helpful for public policy purposes.

## Appendix

Proof of Lemma 1:

i) If $\eta_i > L/(d+pr)$, the expert has more customers than she can handle with honest behavior. Given her time constraint, she is only interested in the profit per hour repair $(R_i - r)/r$ compared to the profit per hour diagnosis $(D_i - d)/d$. If $R_i = rD_i/d$, which implies $(R_i - r)/r = (D_i - d)/d$, she is indifferent between diagnosis and repair and, therefore, behaves honestly. If $R_i > rD_i/d$, she prefers repair to diagnosis and thus repairs too much and vice versa if $R_i < rD_i/d$.

ii) If $\eta_i = L/(d+pr)$ the expert fully utilizes her capacity with non-fraudulent behavior. If $R_i < rD_i/d$, she strictly prefers diagnosis to repair; yet she makes diagnoses for her entire clientele. She has to repair to use up her remaining time $L - \eta_1 d$; honestly fixing the bad products of her clientele just exhausts her capacity. If $R_i = rD_i/d$, the argument is along similar lines as i). If $R_i > rD_i/d$, the expert strongly prefers repair to diagnosis. Hence, she will repair all products she diagnoses and treat fewer than $\eta_i$ customers.

iii) If $\eta_i < L/(d+pr)$ expert $i$ has unused capacity with non-fraudulent behavior. As long as $R_i > 0$, she makes money by repairing some more products to use her idle capacity. Only when $R_i = 0$ the incentive for too much repair disappears.

Q.E.D.

Proof of Lemma 2:

i) We first consider the price games with $j = 1, \ldots, k$ active experts. If $\eta_i \geq L/(d+pr)$, Lemma 1 implies that prices $(D_i, R_i) = (dw, rw)$ induce non-fraudulent repair. Honest services at these prices generate utility $\bar{U}$ so that all consumers wish to buy unless there are better alternatives. Accordingly, if all experts charge $(dw, rw)$, they all have a clientele $\eta_i \geq 1/j$, $i = 1, \ldots, j$. Since $j \leq k$, $\eta_i \geq L/(d+pr)$. Expert $i$ makes expected profit $L/(d+pr)[dw+prw] - L = L(w-1)$.

It remains to be shown that expert $i$'s profits do not increase if she unilaterally changes her prices. If she charges prices such that $R_i > rD_i/d$, she sets $\gamma_i = 1$ and treats only $L/(d+r)$ customers. A consumer who is served has utility $q_h - D - R$. The maximum prices he is willing to pay are $D_i \in [0, dw)$ and $R_i = p(q_h - q_\ell) - D_i$. With these prices the expert makes profits $(L/(d+r))[D_i + R_i] - L = L(p(q_h - q_\ell)/(d+r) - 1) < L(w-1)$. Accordingly, if the expert charges the reservation or lower prices in region (I), she works at full capacity but makes lower profits. If she charges prices above the reservation prices, she loses all customers and makes a loss $L$.

If $R_i < rD_i/d$, the expert prefers diagnosis to repair. She diagnoses all products and repairs only to use her otherwise idle capacity. Accordingly, she sets

$$\gamma_i = \begin{cases} L - \eta_i d)/\eta_i r, , & \text{if } L/(d+pr) \leq \eta_i < L/d; \\ 0, & \text{otherwise.} \end{cases}$$

A consumer who is served has utility $q_h - (p - \gamma_i)(q_h - q_\ell) - D_i - \gamma_i R_i$. The maximum prices the consumer is willing to pay are $D_i \in [(q_h - q_\ell)/(r/d + 1/\gamma_i); \gamma_i(q_h - q_\ell)]$ and $R_i = (q_h - q_\ell) - D_i/\gamma_i$. With these prices the expert makes profits $(L/(d+\gamma_i r))\,[D_i + \gamma_i R_i] - L = L[\gamma_i(q_h - q_\ell)/(d + \gamma_i r) - 1] \leq L(w-1)$. Note that the inequality is strict for $j < k$. If the expert charges the reservation or lower prices in region (II), she works at full capacity yet her profits do not increase. If she charges prices above the reservation prices, she loses all customers and makes a loss $L$.

If $R_i = rD_i/d$ and $D_i < dw$, profits are obviously lower than $L(w-1)$; if $D_i > dw$, the expert has no customers and makes a loss $L$.

The results on uniqueness for these price games follow immediately from the proof of proposition 1 in Emons (1995).

ii) Consider now the price game with $(k+1)$ active experts. If $\eta_i < L/(d+pr)$, Lemma 1 implies that prices $(D_i, R_i) = (0,0)$ induce non-fraudulent repair. Honest services at these prices generate utility $p(q_h - q_\ell)$ so that all consumers wish to buy. Accordingly, if all experts charge $(0,0)$, they all have a clientele $\eta_i = 1/(k+1) < L/(d+pr),\ i = 1,\ldots,k+1$. Expert $i$ makes expected profit $(1/(k+1))[D_i + pR_i] - L = -L$.

It remains to be shown that expert $i$ cannot increase her profits if she unilaterally increases her prices. It is obvious that with *any* price increase the utility of expert $i$'s customers falls below $p(q_h - q_\ell)$. Accordingly, if expert $i$ raises her prices, all her $1/(k+1)$ customers will try to consult the other experts. Since the $k$ non-deviating experts have idle capacity of $1/(k+1)$, they can provide honest services to all of expert $i$'s customers. Since the prices $(0,0)$ are on the equal compensation line $R = rD/d$, the non-deviating experts have proper incentives with $1/k$ customers. All of expert $i$'s customers are therefore served honestly by the non-deviating experts. Consequently, with any positive prices expert $i$ loses all her customers to her colleagues, making such a price increase unattractive.

Given these results, the price game with $k+1$ experts has the same basic structure as the Bertrand game without capacity constraints. Uniqueness follows from using the standard undercutting arguments; see, e.g., Tirole (1988).

Q.E.D.

Proof of Lemma 3 :

Suppose all experts but the first enter with probability $\sigma_i := \sigma = \sqrt[k]{1-1/w}$, $i = 2,\ldots,k+1$ so that with probability $\sigma^k$ all of them are active and with the complementary probability $(1-\sigma^k)$ not all of them are in the market. Expert 1's expected profit from entering with probability $\sigma_1$ is $\sigma_1[(1-\sigma^k)L(w-1) - \sigma^k L] = \sigma_1 0 = 0$. Accordingly, expert 1 is indifferent between her two pure strategies and playing $\sigma_1 = \sigma$ is indeed a best response to $\sigma_i = \sigma,\ i = 2,\ldots k+1$.

Q.E.D.

Proof of Lemma 4 :

Suppose $\sigma_i = 1,\ i = 1,\ldots,k+1, i \neq j$. Then expert $j$'s expected profit from entering with probability $\sigma_j$ is $\sigma_j(-L)$ which is maximized by $\sigma_j = 0$. If $\sigma_i = 1,\ i = 2,\ldots,k, i \neq j$ and $\sigma_j = 0$, expert 1's expected profit from entering with probability $\sigma_1$ is $\sigma_1 L(w-1)$ which is maximized by $\sigma_1 = 1$.

Q.E.D.

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## Endnotes

1) To give a few examples: In the Swiss Canton of Ticino 'ordinary patients' (i.e., the population average) had 33% more of the seven most important operations than medical doctors and their families. Interestingly enough, lawyers and their loved ones have about the same operation frequency as the families of medical doctors (Domenighetti et al. (1993)). In Germany the most expensive shops charge up to double of what the cheapest garages charge for bodywork without necessarily being any better (ADAC Motorwelt 11/92). In the US unnecessary repairs were recommended to car owners by employees of Sears Automotive Centers in 90% of the test cases (Wall Street Journal 6/23/92).

2) Other related theoretical papers include Milgrom and Roberts (1986), Glazer and McGuire (1993), Pitchik and Schotter (1993), Dana and Spier (1993), and Wolinsky (1995). For an experimental study mimicking a market for expertise, see Plott and Wilde (1991).

3) We make the continuum assumption not only for notational convenience. With a finite number of consumers we run into the following problem. Suppose an expert expects a clientele with $(1-p)$ good and $p$ bad products. With a finite number of customers, however, the actual realization of her clientele will be different from the expected one. Accordingly, at the end of the day she will realize that she has either too little or excess capacity and she will start behaving fraudulently. With a continuum of customers we do not encounter this difficulty which would complicate the analysis substantially.

4) This is the standard assumption made in literature; see, e.g., Nitzan and Tzur (1991), Wolinsky (1993), or Taylor (1995). It captures in a straightforward manner the idea that it is cheaper to provide diagnosis and repair jointly rather than separately. An exception is the paper by Demski and Sappington (1987).

5) While the assumption that total demand is an integer multiple of the individual capacity is crucial to our results, the assumption on the overall number of experts is made only for the ease of exposition. We will comment on the integer assumption in due course.

6) The fraudulent expert problem may disappear if consumers purchase long term insurance contracts that fully cover all repairs *and* forgone services during the entire product life; such covenants are commonly known as service or health maintenance plans. With these contracts experts have correct incentives since they bear all marginal costs. Yet such long term insurance contracts are particularly prone to consumer moral hazard so that in equilibrium consumers may purchase no service maintenance plans. The problem of too little repair may be solved by a short term warranty for lost services: if the product fails, the expert pays the consumer a sufficiently large amount of money. An honest expert may offer such a warranty at a lower cost than an expert who, say, doesn't repair at all. Such warranties provide experts with an incentive not to cheat. Yet, they may easily fail to do the job when there is consumer moral hazard in the last stage of product life. See Emons (1988).

7) A few remarks for those readers who feel that games should be written down properly: Since players choose simultaneously in stages one, two, and three, we have a game of 'almost

perfect' instead of 'perfect' information; see, e.g., Tirole (1988), 431-432. After stage four payoffs are determined as follows. First nature chooses whether the product is in good or bad shape. Then players follow their plans of stages one to four. Finally, nature decides whether the product works or fails and the actual payoffs are realized.

8) In the principal-agent literature a related result is known as the equal compensation principle. See, e.g., Milgrom and Roberts (1992), 228-232.

9) Darby and Karni (1973) also point out that the sellers' incentives depend on the state of demand. When there is 'no customer waiting for service', sellers have an incentive to oversell their services to utilize idle resources; this incentive to oversell disappears when 'the length of the queue of customers waiting for service is positive'. Darby and Karni do not discuss that the sellers' incentives also depend on prices.

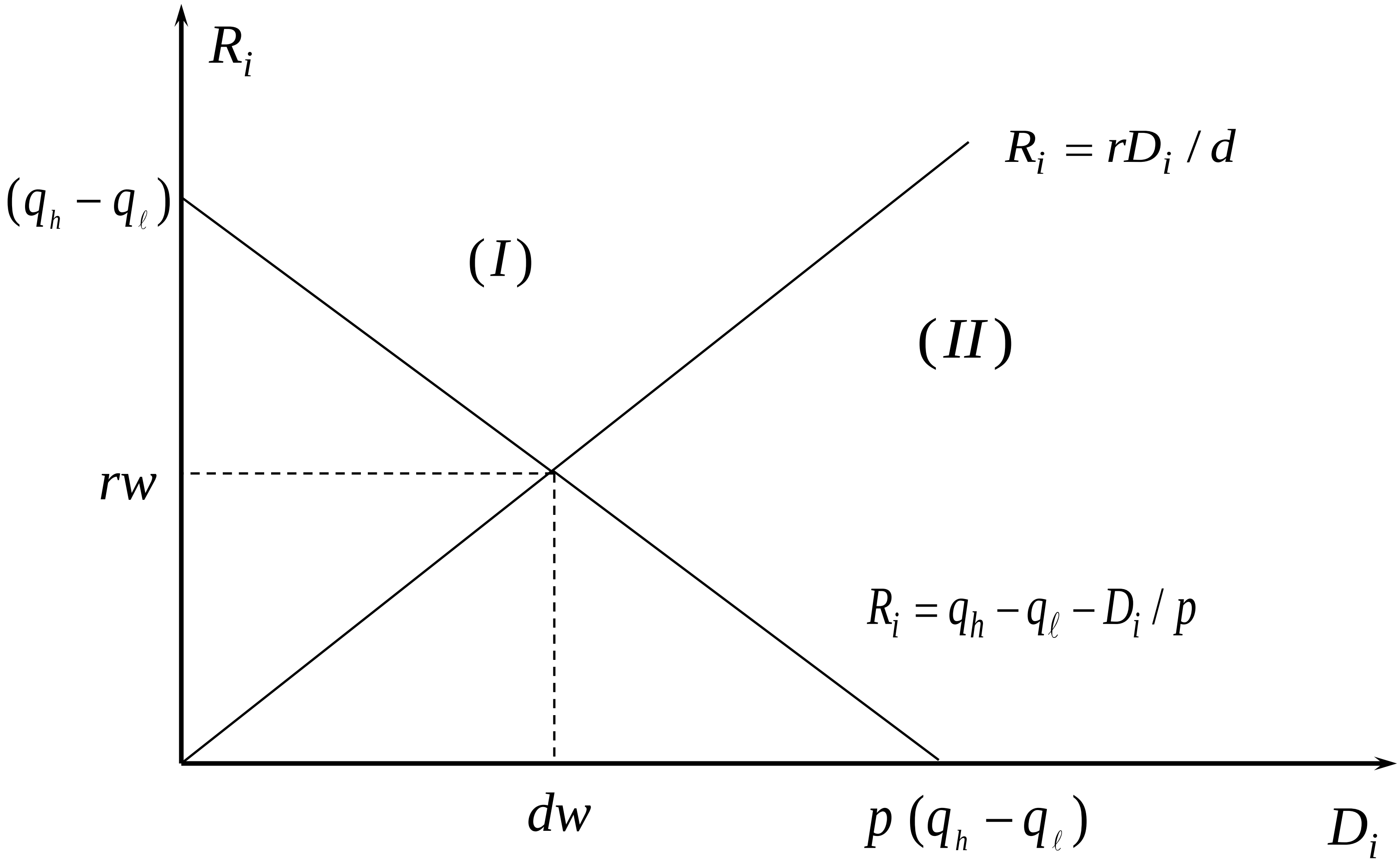


Figure 1: The Equal Compensation Line and Consumers' Reservation Prices for Honest Services