

# A Theory of Certification with an Application to the Market for Auditing Services\*

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## Abstract

The paper develops a theory which attempts to understand segmentation and fee-setting in certification markets. The basis for the theory is that certifiers offer differentiated tests; for a given object it may be more difficult to pass the test of certifier  $i$  than the test of certifier  $j$ . Given the test standards, certifiers compete for customers via their fee-setting. In equilibrium, sellers with low unobservable quality self-select to a lenient test and sellers with high unobservable quality self-select to a stricter test. Moreover, sellers selecting an easy test pay a lower (endogenous) certification fee than sellers selecting a difficult test. As a test of the theory, I analyze Norwegian panel data to investigate whether firms affiliated with a cheaper or a non-Big 5 auditor have worse (unobservable) characteristics, measured by subsequent drops in sales, assets or equity. The empirical analysis supports the theory.

Keywords: Adverse Selection, Auditing, Investment Banking, Oligopoly theory, Signaling.

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# 1 Introduction

Certifiers are third parties in the trading process with some ability to assess quality before trade takes place. A seemingly pervasive characteristic of certification markets is that different certifiers serve different quality segments. For example, venture capitalists finance the more promising start-ups, the equity offerings of highest quality are underwritten by the "Big 8" investment banks (Choi, 1996) and by Big 5 auditors, or, closer to home, prestigious journals publish papers of higher quality than other journals. Consequently, being affiliated with a certain certifier gives a value-relevant signal: an IPO will be less underpriced if the firm is venture capitalist backed (Megginson & Weiss, 1991), and less underpriced if underwritten by a commercial bank than by an investment bank (Puri, 1996), equity or debt offerings underwritten by Big 5 accounting firms get a more favorable market response than offerings underwritten by non-Big 5 accounting firms (Toeh & Wong, 1993, Mansi et al., 2004), and the value of a publication in *Econometrica* is higher than the value of a publication in most other journals.

We can think of several possible explanations for segmentation. One would be that the certifier (or certifiers) with most reputation capital would give the most trustworthy reports, and therefore be the most attractive certifier for high quality sellers. However, this approach seems inadequate to explain why the certifier with most reputation capital does not capture the whole market. In a similar vein, segmentation could occur because the high-quality sellers prefer to attend the certifier (or certifiers) with the most precise testing technology. However, in that case, it would be unclear why the medium-quality sellers would not also prefer the most precise test, and so on until only the lowest-quality sellers (if any) would attend a certifier with an imprecise test. In contrast, the present theory is based on the assertion that different certifiers have tests that cannot be ranked in terms of precision, but can be ranked in terms of passing difficulty. For example, a leading investment bank such as Goldman Sachs will be more hesitant to underwrite a low quality Initial Public Offering than a regional investment bank; or a Big 5 auditor will be less likely to pass (or be affiliated with) a firm with dubious accounting practices than a regional auditor, a paper of given quality is harder to get accepted in *Econometrica* than in most other journals.

The first part of the paper builds a simple model of oligopolistic certification around the idea of differences in test standard. The model produces two main predictions. First, under a simple sufficient condition on the stochastic structure of tests, seller groups are segmented according to (ex-ante unobservable) quality in equilibrium. In the case of two active certifiers, which I focus on, sellers with the lowest quality skip certification, sellers with an intermediate quality attend the certifier with the lenient standard, and the high-quality sellers attend the certifier with the strict standard. This insight is similar to that obtained in vintage models of signaling such as Guasch & Weiss (1981) and Titman & Trueman (1986). However, these papers, and others in the signaling literature, assume an exogenous fee structure and is therefore unable to yield predictions along this dimension. Interestingly, the present theory gives an unambiguous prediction on the endogenous fee-setting by certifiers. In short, the equilibrium fees will be monotonic: the certifier attracting sellers of higher quality will charge a higher fee than the certifier attracting lower quality sellers. The model thus produces segmentation of sellers to different certifiers in equilibrium, as the motivation above called for, and equally importantly a clear-cut prediction on fee structure that may be brought to data.

To assess the empirical validity of the model in a concrete setting, the second part of the paper focuses on the market for auditing services. Section 5 relates the theory to established insights from the accounting literature, focusing on fee and quality differences between Big 5 and non-Big 5 auditors. It is shown that the theory can explain stylized facts from the literature on auditor choice and auditor fees, facts that are unexplained or only partially explained by existing theory. Section 6 performs some independent empirical analysis on Norwegian panel data covering more than 7000 firms between 2000 and 2002. I investigate whether having a more expensive (or a Big 5) auditor is associated better (unobservable) firm characteristics, measured by subsequent drops in sales, assets or equity. The empirical analysis is supportive of the theory.

## 2 Related Literature

In the certification intermediary literature, Biglaiser & Friedman (2001) builds on Biglaiser (1993) to consider a certification model with discrete product quality where symmetric

certifiers compete for customers through their pricing rule. Lizzeri (1999) shows that a monopoly certifier with a perfect test can capture all the surplus in the market by essentially revealing nothing about product quality. For more than one certifier, this surprising result is reversed; oligopolistic certifiers reveal all information about product quality and set fees equal to zero. The present theory, in contrast, explains why segmentation might occur in certification markets, a question that received theories of certification does not address.

Guasch & Weiss (1981) considers a schooling model where students pick a school quality, or passing standard, in the same fashion as in the present paper. In particular, tests are of pass/fail nature, and good students self-select to tests with a higher passing standard than inferior students. The main difference to Guasch & Weiss (1981) is that their model has fees as an exogenous variable. In contrast, my model allows the intermediary to profit maximize through their fee setting.<sup>1</sup> The same point applies to the model of Titman & Trueman (1986), which imposes exogenously that auditors of higher quality (in the sense of providing a less noisy signal about a firm's value) charge a higher auditing fee than auditors of lower quality. Under the same type of assumptions as Titman & Trueman (1986), a paper by Puri (1999) obtains segmentation of low and high quality security issues to different underwriters (commercial and investment banks which act as certifiers).

A related literature considers the reputational incentives for stock market analysts (Trueman 1992, Ottoviani & Sorensen, 2003a and 2003b, Morgan & Stocken, 2003). This literature takes the ability or vestedness of the analyst as unknown to investors and explores the quality of information being transmitted in equilibrium. In contrast, I focus on a setting where the ability and incentives of the middleman is known to the market, and where the endogenous variables of interest is seller behavior and certifier fee setting.

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<sup>1</sup>This feature brings the model closer to models of vertical product differentiation such as Shaked & Sutton (1984). In this literature, there is to my knowledge no notion of middlemen revealing information.

### 3 The Model

There are sellers, certifiers, and a market for objects, all agents being risk-neutral. Each seller is equipped with an object with value  $q$  to the market and value 0 to himself. The value  $q$  is known to the seller, while the market merely knows that the distribution of objects follows the frequency function  $h(q)$ , with support  $[a, 1]$ . For simplicity, I assume that  $E(q) = \int_a^1 qh(q)dq < 0$ , there will be no trade without certifiers present in the market.

There are finitely many active certifiers in the market. This assumption can be justified by the considerable fixed costs in acquiring expertise in testing products (or in acquiring reputation for producing honest reports). The formal analysis is limited to the monopoly case ( $n = 1$ ) and the duopoly ( $n = 2$ ) case.<sup>2</sup>

Certifier  $i$  operates a test grid with  $K$  levels,  $\{I_i^1, I_i^2, \dots, I_i^K\}$ , where  $I_i^1 < I_i^2 < \dots < I_i^K \in \mathfrak{R}$ . The test identifies which interval  $\hat{q}_i$  lies on, where  $\hat{q}_i$  is a noisy measure of  $q$ . For simplicity, I assume that the noise in the test is independent of the object's true quality, i.e.,  $\hat{q}_i = q + \varepsilon_i$ , where  $\varepsilon_i$  is white noise with density function  $f_i(x)$ .<sup>3</sup> There are hence  $K + 1$  possible test results, where the object obtains the test result  $m$  if  $I_i^m < \hat{q}_i < I_i^{m+1}$ , where  $m \in \{1, 2, \dots, K + 1\}$ . The analysis focuses on the special case of binary tests ( $K = 1$ ).<sup>4</sup> Thus there are only two possible test results, where an object obtains the test result 0 from certifier  $i$  if  $\hat{q}_i < I_i$  and obtains the test result 1 if  $\hat{q}_i > I_i$ . For convenience, I label the 0-result by "fail" and the 1-result by "pass".<sup>5</sup> The test standards  $\{I_i\}_{i=1, \dots, n}$  are taken as exogenous, an assumption that will be discussed later.

Although obviously a strong simplification, binary tests seem to be a reasonably good approximation to what goes on in several certifying markets, such as the market for auditing reports, MBA degrees, driving licenses, marine vessel certification, industrial

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<sup>2</sup>For the analysis of a version of the model with endogenous entry, see Hvide & Heifetz (2002).

<sup>3</sup>Extremely product qualities could be easier to distinguish than mid-range qualities. Such a feature would just aggravate the result that low-quality objects are not certified. For all but objects of extremely low product qualities, the independence assumption does not seem unreasonable as an approximation.

<sup>4</sup>Although the case with one test standard has several interesting applications, the case with more than one test standard ( $K > 1$ ) is clearly also of interest. As suggested by a referee, one example is Berkeley's electronic journal where papers can be accepted in the A, B, C or D version of the journal depending on the quality of the submission. We leave the case  $K > 1$  as a possible future extension.

<sup>5</sup>This shorthand is slightly misleading as objects that fail may well be traded later on. Hence certifiers in the present model are not *gatekeepers*, as discussed by Choi (1996).

products certification, and bond certification (GAAP standard of accounting or not, admit or not to program, fail or pass safety standards, ISO standard or not, and investment grade/ junk grade).<sup>6</sup> An interesting question that lies outside the scope of the paper is why certifier reports are typically so coarse. As indicated by the interesting Morgan & Stocken (2003), one reason can be that a rich "language" is redundant if the certifier has some stake in keeping the seller afloat.

The timing is as follows. First, the certifiers compete in fees, taking the test standards as given. Certifier  $i$ 's fee is labeled by  $F_i \in \mathfrak{R}_+$ . Note that I am implicitly assuming that a certifier cannot price discriminate on basis of the result of the test. This is a natural requirement, since such price discrimination would imply that the certifier would have ex-post incentives to always fail (or pass) the object.<sup>7</sup> Given the fee setting, sellers decide simultaneously which certifier to attend (if any) after observing  $\{F_i, I_i\}_{i=1, \dots, n}$ . If a seller decides to attend certifier  $i$ , he pays  $F_i$  to that certifier, and the test is performed. The test result is then reported publicly (by unraveling arguments such as in Milgrom 1981, the case where tests are reported privately to sellers is equivalent). By the assumption that the fee does not depend on the test outcome, there will be no incentives for certifiers to fraud tests, and we assume that they are reported truthfully.<sup>8</sup> The product market is assumed to be competitive, meaning that a seller obtains a price for his product equal to its expected quality, conditional on which certifier attended to (if any), and the test report.

## 4 Monopoly

To illustrate the model, let me begin by considering the case with only one active certifier in the market. I assume (and show later) that equilibrium has a connected structure: sellers on the interval  $[a, q_1]$  do not attend the certifier, and sellers on the interval  $[q_1, 1]$

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<sup>6</sup>Although credit rating agencies have an arsenal of possible grades, empirical studies show that the real difference in grade is between investment bond grade (BB and higher) and junk bond (B and lower).

<sup>7</sup>Reputation concerns, modeled by for example Ottoviani & Sorensen (2004), could support price discrimination as an equilibrium strategy. This would require a more dynamic setup.

<sup>8</sup>If the certifier has an equity-like stake in the object, sellers and certifiers could have incentives to collude in frauding reports, as might have occurred in the Andersen-Enron case. The present model does not consider that very interesting issue, which is confronted in Morgan & Stocken (2003).

do attend the certifier, where the seller with quality  $q_1$  is indifferent between attending the certifier or not. In this section, I assume for simplicity that objects are uniformly distributed, i.e., that  $h(q)$  is constant.

The expected utility for an agent with quality  $q$  for attending a certifier with test standard  $I$  and fee  $F$ , taking the cutoff  $q_1$  as given, equals the expected market posterior of quality after the test has been made public, subtracted the cost of certification,

$$U(q; q_1) = \Pr(\text{pass}|q, I)U(\text{pass}) + \Pr(\text{fail}|q, I)U(\text{fail}) - F \quad (1)$$

where,

$$\begin{aligned} \Pr(\text{pass}|q, I) &= \int_{I-q}^1 h(x)dx \\ \Pr(\text{fail}|q, I) &= 1 - \Pr(\text{pass}|q, I) \end{aligned} \quad (2)$$

$U(\text{fail})$  and  $U(\text{pass})$  denote the expected quality (and hence price obtained) for an object that passes and fails the test, respectively, given that all reports are made public in the market. Since there is a continuum of sellers, each seller takes  $U(\text{fail})$  and  $U(\text{pass})$  as constants (these constants are derived in the Appendix). The probability of passing the test increases in  $q$ , and therefore  $U(\text{pass}) > U(\text{fail})$ . It follows that  $U'(q; \cdot) > 0$ ,  $\forall q \in [q_1, 1]$  since  $\Pr(\text{pass}|q, I)$  increases in  $q$  from (2).

It will be useful to define the (expected) gross utility for attending the certifier,  $UU(q, \cdot)$  as,

**Definition 4.1**  $UU(q; q_1) = \Pr(\text{pass}|q, I)U(\text{pass}) + \Pr(\text{fail}|q, I)U(\text{fail})$

The  $UU(q; \cdot)$  function gives the expected market posterior after the test result is revealed for an object with true value equal to  $q$ . Let me collect two useful properties of the  $UU(q; \cdot)$  function.

**Remark 1** *i)*  $q_1 < UU(q; q_1) < 1$ ,  $q \in [q_1, 1]$ , and *ii)*  $\frac{1}{2} < \frac{\partial UU(q_1; q_1)}{\partial q_1} < 1$ .

**Proof.** *i)* follows directly from the test being imperfect and Bayesian updating by the market. To see that *ii)* holds, observe that a perfectly non-informative test has

$\frac{\partial UU(q_1; q_1)}{\partial q_1} = \frac{\partial}{\partial q_1} \left( \frac{q_1 + 1}{2} \right) = \frac{1}{2}$ , and a perfectly informative test has  $\frac{\partial UU(q_1; q_1)}{\partial q_1} = 1$ , with imperfectly informative tests lying in between. ■

The cutoff  $q_1$  is determined by the marginal seller, i.e., the seller that is indifferent between attending the certifier and not. Since the utility for sellers that do not attend a certifier must be zero (no trade),<sup>9</sup>  $q_1$  can be defined implicitly through the equation,

$$\Psi(F, q_1) = UU(q_1; q_1) - F = 0 \quad (3)$$

Since  $\Psi(F, q_1)$  decreases strictly in  $F$  and increases strictly in  $q_1$  from Remark 1, equation (3) defines  $q_1$  implicitly as an increasing function of  $F$ . By the implicit function theorem,  $\frac{dq_1}{dF}$  can be determined as,

$$\frac{dq_1}{dF} = -\frac{\Psi_F}{\Psi_{q_1}} = \frac{1}{\Psi_{q_1}} > 0 \quad (4)$$

where subscripts denote partial derivatives. This expression is greater than zero by Remark 1, since  $\frac{1}{\Psi_{q_1}} = \left[ \frac{\partial UU(q_1; q_1)}{\partial q_1} \right]^{-1} > 0$ . Economically, this means that a higher fee implies that the marginal seller must be of higher quality.

Let me now consider the monopolists profit maximization problem. Assuming zero fixed and variable costs of certification for convenience, the monopoly profits are,

$$\Pi = F(1 - q_1) \quad (5)$$

The optimal  $F$  solves the first order condition,

$$\frac{d\Pi}{dF} = 1 - q - \frac{dq_1}{dF} F = 0 \quad (6)$$

Since  $\frac{dq_1}{dF} > 0$  from equation (4), equation (6) shows that a higher fee brings a positive

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<sup>9</sup>This follows from the assumption that  $E(q) < 0$ . With  $E(q) > 0$  then the utility for not being certified can be greater than zero, since these objects may also be traded. Say for illustration that  $a = 0$ . Then the utility of not being certified equals  $\frac{q_1}{2}$  (average quality of sellers that do not attend the certifier). Apart from that, the equilibrium will have the same qualitative features.

direct effect on profits but a negative indirect effect through a higher  $q_1$ .<sup>10</sup>

Denoting the equilibrium value of  $q_1$  by  $q_1^*$ , the following can be noted.

**Remark 2** *Monopoly equilibrium.* The monopolist sets a fee for certification such that  $q_1^* > 0$ . Hence no lemons will be certified in equilibrium, but some non-lemons, i.e., with  $q \in [0, q_1^*]$ , will not be certified.

**Proof.** Clearly  $q_1^*$  must be on the interior of  $Q$  and hence it is sufficient to show that  $\frac{d\Pi}{dF} > 0$  for  $q_1 \leq 0$ . I start out by considering the case  $q_1 = 0$ . In that case, we can see from (3) that  $F = UU(0, 0)$ . Inserting into the expression for  $\frac{d\Pi}{dF}$  in (4), we get,

$$\frac{d\Pi}{dF}_{q_1=0} = 1 - \frac{UU(0, 0)}{\Psi_{q_1}(0)} \quad (7)$$

By Remark 1,  $\frac{1}{2} < \frac{\partial UU(q_1; \cdot)}{\partial q_1} < 1$  for any  $q_1$ . Hence  $\frac{1}{\Psi_{q_1}(0)} = \left[ \frac{\partial UU(q_1; \cdot)}{\partial q_1} \right]_{q_1=0}^{-1} > 1$ . But, since  $UU(0, 0) < 1$  by Remark 1, we must have that  $\frac{UU(0, 0)}{\Psi_{q_1}(0)} < 1$ . It follows that  $\frac{d\Pi}{dF}_{q_1=0} > 0$ . By the same argument, it follows that  $\frac{d\Pi}{dF}_{q_1 < 0} > 0$ . Hence  $\frac{d\Pi}{dF} > 0$  for  $q_1 \leq 0$ , and  $q_1^* > 0$  follows. ■

The intuition for the result can be understood in terms of standard monopoly theory. While the socially optimal cutoff is  $q_1 = 0$ , in which case no lemons ( $q < 0$ ) will be traded and all non-lemons ( $q > 0$ ) will be traded, the monopolist maximizes profits with a fee that results in too low trade volume ( $q_1^* > 0$ ), because it maximizes own revenue rather than social surplus. The result illustrates the impact of assuming an imperfect test structure: in the setting of Lizzeri (1999), tests are perfect and the certifier will in effect pick the socially efficient cutoff (0). However, since the certifier also will extract all the surplus in the market in Lizzeri (1999), as shown by Albano & Lizzeri (2001) the equilibrium will give weak incentives for sellers to make investments in quality. In the

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<sup>10</sup>The second order condition for profit maximum is,

$$\frac{d^2\Pi}{dF^2} = -\frac{dq}{dF} - F \frac{dq^2}{dF^2} = -\frac{1}{\Psi_{q_1}} - F \frac{\Psi_{q_1 q_1}}{\Psi_{q_1}^2} < 0.$$

present setting, there will be incentives to make investments in quality since a higher quality implies a higher probability of passing the test, and therefore a higher expected market value.

The reason for why the upper cutoff must equal 1 is that if the sellers on the top had incentives to deviate, then this must also be true for the sellers immediately below and unraveling would follow. So in any equilibrium with certification it must be true that the sellers attending the certifier is a connected set  $[q_1^*, 1]$ .<sup>11</sup> For a candidate  $q_1^*$  higher than the solved for,  $\Psi$  is positive, and there will be sellers that can obtain a higher utility by attending the certifier rather than not attending the certifier.<sup>12</sup>

## 5 Duopoly

Let us now consider equilibria in a market with  $n$  active certifiers, where  $n$  is taken to equal 2 for expositional clarity. I consider the case with unequal test standards  $I_1 \neq I_2$ , and apply the convention  $I_1 < I_2$ . The assumption  $I_1 \neq I_2$  is uncontroversial, since the choice of equal test standard  $I_1 = I_2$  would imply (undifferentiated product) Bertrand competition, resulting in zero profits for both firms. As in models of vertical product differentiation (e.g., Salop, 1979), this would not be an equilibrium outcome for virtually any cost structure.

The expected utility from attending certifier  $i$  for an agent with quality  $q$ , denoted by  $U_i(q; \cdot)$ , equals,

$$U_i(q; \cdot) = \Pr(\text{pass}_i|q, I_i)U_i(\text{pass}) + \Pr(\text{fail}_i|q, I_i)U_i(\text{fail}) - F_i \quad (8)$$

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<sup>11</sup>Imposing the intuitive criterion will eliminate the equilibrium where no agents attend the certifier because it fears that the market will ignore the information lying in the test result.

<sup>12</sup>In the monopoly case, profits will be maximized for an uninformative test ( $\sigma = \infty$ ). This result mirrors the finding from Lizzeri (1999), Theorem 1, where the monopolist certifier chooses an uninformative test in optimum. The intuition for the result in our setting is that when  $\sigma$  gets higher, setting a higher price will result only in a small change in  $q_1$ , since  $U'(q; \cdot)$  is close to zero, and hence the monopolist will charge a price close to  $1/2$  as  $\sigma$  tends to infinity, and take all the surplus in the market. Even if having a very imprecise test can be profitable in the monopoly case, in the oligopoly case such a test would make it too easy for the other certifiers (who has more informative tests) to steal sellers, and would not be optimal. Unfortunately, it is hard to come up with a very precise formal statement of this intuition.

where  $U_i(\text{pass})$  is the average quality of the objects that pass test  $i$ ,  $U_i(\text{fail})$  is the average quality of the objects that fail test  $i$ , and

$$\Pr(\text{pass}_i|q, I_i) = \int_{I_i-q} f_i(x)dx = 1 - \Pr(\text{fail}_i|q, I_i)$$

In an equilibrium where both certifiers attract a positive measure of sellers, there must exist at least one value of  $q$  such that  $U_1(q; \cdot) = U_2(q; \cdot)$ . Define  $\Phi(q; \cdot) = U_1(q; \cdot) - U_2(q; \cdot)$ , and then define the set  $Q_2$  as,

$$Q_2 = \{q : \Phi(q; \cdot) = 0\} \tag{9}$$

The set  $Q_2$  contains the points of indifference between attending certifier 1 and certifier 2. I denote by  $\tilde{q}$  an arbitrary element in  $Q_2$ , and consider equilibria with the following structure: for at least one  $\tilde{q}$  sellers with a  $q$  immediately below  $\tilde{q}$  prefer to attend certifier 1, and sellers with a  $q$  immediately above  $\tilde{q}$  prefer to attend certifier 2. This property is denoted by the "crossing property".

**Definition 5.1** *The crossing property (CP) holds if there exists  $q \in Q_2$  such that i)  $\Phi(q - \epsilon) > 0$ , and ii)  $\Phi(q + \epsilon) < 0$ , for  $\epsilon$  sufficiently close to zero.*

It will be shown that the local condition CP implies connectedness of equilibria, given that a sufficient condition the test technology (Assumption 1) holds. First a definition.

**Definition 5.2** *Single crossing property (SCP) holds if for any  $q \in Q_2$  and  $\epsilon > 0$ , then  $\Phi(q - \epsilon) > 0$  and  $\Phi(q + \epsilon) < 0$ .*

In economic terms, SCP means that if a seller of quality  $q$  prefers the difficult test, then the same must be true for a seller with  $q' > q$ . Analogously, if a seller with quality  $q$  prefers the easy test then the same must be true for a seller with  $q' < q$ . If SCP holds, then there exists only one value of  $q$  that makes sellers indifferent between attending the two certifiers, and connectedness follows. We now put a common restriction on  $h(\cdot)$  to ensure that SCP holds.

**Assumption 1.**

The likelihood ratio  $h_1(I_1 - q)/h_2(I_2 - q)$  decreases in  $q$ , for all  $q \in Q$ .

A decreasing likelihood ratio (DLRP) implies that the higher  $q$ , the higher is the relative probability of passing the difficult test compared to the easy test. Although one can certainly think of stochastic environments where this assumption does not hold, DLRP seems almost as a defining property of two tests having different strictness. Similar conditions to the decreasing likelihood ratio function are often assumed to hold in the moral hazard literature (see e.g., Holmstrom 1979), and is satisfied for a range of joint distributions.

For example, let  $\varepsilon_1$  and  $\varepsilon_2$  be *iid* normally distributed with variance  $\sigma^2$ , to obtain,

$$\begin{aligned} h_1(I_1 - q; \cdot)/h_2(I_2 - q; \cdot) &= \frac{1}{\sigma\sqrt{2\pi}}e^{-(I_1-q)^2/2\sigma^2} / \frac{1}{\sigma\sqrt{2\pi}}e^{-(I_2-q)^2/2\sigma^2} \\ &= e^{-\frac{(I_2 - I_1)(I_2 - 2q + I_1)}{2\sigma^2}} \end{aligned} \quad (10)$$

This expression decreases in  $q$  since  $I_1 < I_2$ , and hence DLRP is satisfied.

We now have the following lemma.

**Lemma 1** *CP implies connectedness.*

**Proof.** Suppose that CP holds in the point  $\tilde{q}$ , i.e.,  $\tilde{q} \in Q_2$  and  $\frac{\partial\Phi(q)}{\partial q}_{q=\tilde{q}} < 0$ . Recall that  $U_i(q; \cdot) = \Pr(\text{pass}_i|q, I_i)U_i(\text{pass}) + [1 - \Pr(\text{pass}_i|q, I_i)]U_i(\text{fail}) - F_i$ , and observe that only the  $\Pr(\text{pass}_i|q, I_i)$  terms in this expression depend on  $q$ . Further observe that  $\frac{\partial\Pr(\text{pass}_i|q, I_i)}{\partial q} = h_i(I_i - q)$ , and define  $\Delta_i = U_i(\text{pass}) - U_i(\text{fail})$ . We then have,

$$\begin{aligned} \frac{\partial\Phi(q; \cdot)}{\partial q} &= U_1'(q; \cdot) - U_2'(q; \cdot) \\ &= h_1(I_1 - q)\Delta_1 - h_2(I_2 - q)\Delta_2 \end{aligned} \quad (11)$$

For an arbitrary value of  $q$ , this expression is negative if,

$$\theta = \frac{h_1(I_1 - q)\Delta_1}{h_1(I_2 - q)\Delta_2} < 1 \quad (12)$$

Since  $\frac{\Delta_1}{\Delta_2}$  is a constant, it is sufficient for SCP to hold that the likelihood ratio  $h_1(I_1 -$

$q)/h_2(I_2 - q)$  decreases in  $q$  for  $q > \tilde{q}$ , which is ensured by Assumption 1. Hence CP implies SCP and connectedness. ■

Assumption 1 ensures that if a seller with a given quality prefers test 2 to test 1 then a seller with a higher quality also prefers test 2 to test 1. It follows that equilibria must be connected, and a unique divide is obtained between the sellers that prefer to attend certifier 1 and to attend certifier 2, respectively. This result is obtained without making any assumptions about fee-setting behavior.

In an equilibrium where both certifiers are active, there must exist a seller that is indifferent between attending certifier 1 and not attending a certifier. The cutoff value of  $q$ , denoted by  $q_1$ , can be defined implicitly through the equation,

$$UU_1(q_1, \cdot) - F_1 = 0 \quad (13)$$

As can be seen by the same type of argument as in the monopoly case,  $q_1$  is uniquely determined for given values of  $(F_1, q_2)$ . I denote by  $q_1^*$  the equilibrium value of  $q_1$ . Then the following holds.

**Lemma 2** *i) In an equilibrium with two active certifiers, CP implies that  $q_1^* < q_2^*$ . ii)  $q_1^* > a$ .*

**Proof.** i) follows from straightforward manipulations, and is skipped. To prove ii), observe that  $q_1^* = a$  would imply that the average quality of those that attend certifier 1 being negative, since  $E(q) < 0$  and certifier 2 attracts the upper end of the market by Lemma 1. But in that case certifier 1 must charge a negative fee, which is not consistent with equilibrium. ■

Note that part ii) means that sellers on  $[a, q_1^*]$  do not attend a certifier in equilibrium. We now have the following.

**Proposition 1** *Segmentation. In an equilibrium with two active certifiers, CP implies that sellers can be split into three connected segments. In increasing order of quality, the segments are: those that do not attend a certifier, those that attend certifier 1, and those that attend certifier 2.*

**Proof.** Follows from Lemma 1 and Lemma 2. ■

This is a key result, since it shows that the model produces equilibria where different certifiers capture different connected segments of the market.

After the testing, sellers will be separated into five groups: those that did not attend a certifier, those that attended certifier 1 and failed, those that attended certifier 1 and passed, those that attended certifier 2 and failed, and finally those that attended certifier 2 and passed. These groups are of strictly increasing quality, and will therefore be traded at strictly increasing prices in the market. An implication is that sellers that attend certifier 2 must (on average) be traded at a higher price than the sellers that attend certifier 1, consistent with one of the stylized facts posited in the Introduction.<sup>13</sup>

Consequently, I can rank certifiers in equilibrium according to the magnitude of the value increase due to attending that certifier: certifier 1 provides a lower value increase for sellers than certifier 2. A natural question is whether this ranking has any implications for the fees set by the certifiers. Will the top ranked certifier always charge a higher fee than a lower ranked certifier? The answer to this question is not obvious; separation is to some extent already ensured by a lower-quality object having a lower probability of passing the difficult test, and it would therefore be conceivable that the top certifier sets a low fee to attract a high fraction of the market.

**Proposition 2** *Pricing behavior. CP implies that  $F_2^* > F_1^*$  in equilibrium.*

**Proof.** Recall that the  $UU_i(q; \cdot)$  functions give the expected market conception ex-post for an agent with ability  $q$  that attends certifier  $i$ . Since CP implies connectedness, by Remark 1, part i), it must be the case that  $UU_1(q; \cdot) < UU_2(q; \cdot)$ . In particular, for agent  $q_2^*$ , which is indifferent between which certifier to attend, it must be the case that  $UU_1(q_2^*; \cdot) < UU_2(q_2^*; \cdot)$ . But the indifference condition says that  $UU_1(q_2^*; \cdot) - F_1^* =$

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<sup>13</sup>The increase in market value for a seller from attending a certifier depends on which certifier attended and on whether a passing grade was obtained. The relative magnitude of these two effects will depend on the informativeness of the tests: if the tests are relatively uninformative (high variance of the  $\sigma_i$ 's) then the difference in market value for attending different certifiers (and, say, passing) will be much larger than the difference in market value from passing or failing a given test. On the other hand, if the tests are relatively informative, then the difference in market value from passing or failing a given test can be almost as large as the difference in market value for passing different tests.

$UU_2(q_2^*; \cdot) - F_2^*$ . Combining these two expressions immediately yields that  $UU_1(q_2^*; \cdot) - UU_2(q_2^*; \cdot) = F_1^* - F_2^* < 0$ , and hence  $F_2^* > F_1^*$  follows. ■

The proposition says that fees will be monotonically increasing: the certifier who attracts the sellers of highest quality will charge a higher fee. The intuition is that a seller knows that if he takes the simple test, the market will believe that his object is of lower quality than if he takes the difficult test (observe that this holds independently of the test outcome). Given this drawback of attending certifier 1, the cost for attending certifier 1 must be lower than the cost for attending certifier 2 for an indifferent seller to exist.

This result is very useful in that it gives a concrete and novel testable hypothesis from the model. Section 7 attempts to test the hypothesis using data from the Norwegian market for auditors.<sup>14</sup>

Let me now consider a numerical example, to illustrate the equilibrium structure.

**Example 1** *Let  $\varepsilon_i$  be normally and independently distributed with mean zero and variance .35.  $h(q) = 1$  for  $q \in Q = [-1, 1]$ . Then for  $I_1 = 0$  and  $I_2 = .35$  we get  $(F_1^*, F_2^*, q_1^*, q_2^*) = (.09, .43, -.03, .25)$  with associated profits,  $\Pi_1^*(\cdot) \approx .04$ ,  $\Pi_2^*(\cdot) \approx .32$ . The average pass rate is .75 for test 1, and .83 for test 2.*

The equilibrium can be illustrated with a figure.

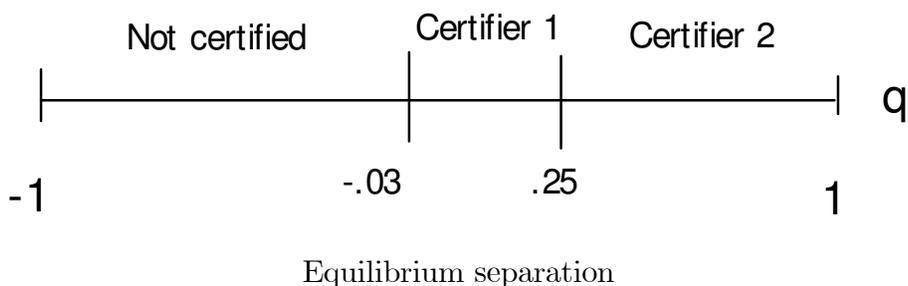
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<sup>14</sup>Let me here make two comments on the uniqueness properties of the model.

First, the crossing property may seem like an obvious property of equilibrium, but in fact there can exist equilibria with the reverse structure of that considered, namely that the middle group of sellers attends the certifier with the highest  $I_i$  and the upper group of sellers attends the certifier with the lowest  $I_i$ . By the same type of argument as in Lemma 1, it can be shown that such equilibria will also be connected, and hence that the equivalent of Proposition 1 and Proposition 2 will also hold.

Second, SCP does not exclude the possibility of a multiplicity of equilibria. The reason for possible multiplicity is that the  $\Phi(\cdot)$  function has  $q_1$  as a free variable, and hence it is possible that more than one value of  $q_1$  (and hence  $q_2$ ) is consistent with equilibrium. Therefore our main results, Proposition 1 and Proposition 2, apply to *every* equilibrium in the equilibrium set, and does not hinge on uniqueness of equilibria.

The underlying reason for the potential multiplicity of equilibria is the *social interaction* aspect of the model: which test a seller wishes to attend depends on the behavior of other sellers, because their behavior determines  $U_i(\text{pass})$  and  $U_i(\text{fail})$ . This aspect of the model is in contrast to related models of product differentiation, see footnote 18.



The sellers between  $-1$  and  $-.03$  do not attend a certifier, the sellers between  $-.03$  and  $.25$  attend certifier 1, and the sellers between  $.25$  and  $1$  attend certifier 2. After the test results have been made public, the market will hold the following belief about the (average) quality of the five groups:  $(-.48, .07, .13, .38, .68)$ , and hence only objects that did not attend a certifier will not be traded in equilibrium.<sup>15</sup>

Since objects between  $-.03$  and  $0$  attend a certifier and are traded in equilibrium, the example shows that lemons may be certified in equilibrium. That result can be stated as a remark.

**Remark 3** *In a duopoly, lemons may be certified.*

Let me explain the intuition for this result in some detail. Recall that certifier 1 attracts the group  $[q_1^*, q_2^*]$ . If  $q_2$  were independent of  $F_1$  then  $q_1^* > 0$ , by the same argument as in Remark 3. However, since  $q_2$  depends on  $F_1$ , then decreasing  $F_1$  to the point where  $q_1^* < 0$  may be profitable for certifier 1, if  $q_2$  increases in  $F_1$ . In a different phrasing, certifier 1 does not internalize the negative externality imposed on certifier 2 from decreasing the fee. Although the effect of having  $q_1^*$  below  $0$  in isolation decreases the certifier 1 profits, the positive effect on profits from increasing  $q_2^*$  outweighs this effect, and we get an inefficient equilibrium where some lemons are certified. Although the algebra is somewhat murky, the result seems to be quite general, in that I have been unable to generate examples with  $q_1^* > 0$ .

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<sup>15</sup>The example suggests that the profits for the upper certifier is higher than the profits for the bottom certifier. I have been unable to generate counterexamples to this assertion, but have also been unable to prove it.

To sum up, I have shown that the model produces equilibria where different certifiers attract different, connected, seller segments. Moreover, a certifier attracting a segment with a higher quality will charge a higher fee than a certifier attracting a lower quality segment in equilibrium. Let me now discuss some points on robustness of these results.

The introduction of variable costs of testing for the certifier would have no effect on the basic segmentation and fee monotonicity result, as can readily be seen from the proofs of Lemma 1 and Proposition 1; such costs would not affect the proofs. Similarly, from the same type of argument as in Lemma 1, DLRP is sufficient to get connected equilibria also in a setting where there are arbitrary many active certifiers with one test standard each.<sup>16</sup>

I have considered a one-shot game where sellers can attend only one certifier. Although this may fit an auditing application, in some certification markets, an object can attend several subsequent certifiers. This could give sellers incentives to hide negative reports. For example, in the market for MBA degrees and in the market for publication of scientific papers, acts of burning rejection slips are not directly observable. However, such hiding can be indirectly observable; being enrolled in a low-ranked MBA program is a pretty strong signal that (at least some) higher-ranked programs declined entry (the case with scientific papers is analogous).<sup>17</sup>

Moreover, a natural extension is to take the test standards as endogenous, in the spirit of the product differentiation literature.<sup>18</sup> Since certifiers will be engaged in "pure" Bertrand competition if they choose identical test standards, there will be incentives for certifiers to differentiate their tests, to create market power, for anything but very

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<sup>16</sup>The generalized Assumption 1 would be that  $f_i(I_i - q)/f_j(I_j - q)$  decreases in  $q$  for all  $i, j$  such that  $I_i < I_j$ .

<sup>17</sup>Broecker (1990) constructs a model where the possibility of borrowers hiding negative 'reports' (declined applications for loan) can have an impact on equilibrium interest rates. In Broecker's theory banks have identical credit test technology and hence that theory cannot explain segmentation.

<sup>18</sup>In product differentiation models, firms first decide on product characteristics and then compete for customers through their pricing decision. In models of vertical product differentiation (e.g., Shaked & Sutton, 1982), firms offer products of different quality, and sellers differ in their willingness to pay for quality. In models of horizontal product differentiation (e.g., Salop 1979), customers have different tastes over products of the same quality. There are several differences between the present model and those models in the product differentiation literature, one being that here, the test product that an agent (seller) wishes to purchase depends not only on properties of the test itself, but also on behavior of the other agents, as discussed in footnote 13.

extreme cost structures, and the main results would hold also in such an extended model. To illustrate the idea of endogenous test standards, we can consider an example. To make the example computationally tractable, I focus on the Stackelberg game where certifiers set their test standards sequentially; the first entering certifier chooses  $I_2$ , and the follower chooses an  $I_1$  after observing the choice of  $I_2$ , where  $I_i \in \{-1, -\frac{3}{4}, -\frac{1}{2}, 0, \frac{1}{2}, \frac{3}{4}, 1\}$ .<sup>19</sup> The cost of choosing  $I_i$  is assumed to be uniformly zero on this set. After observing the choices of  $\{I_i\}_{i=1,2}$ , the certifiers choose  $\{F_i\}_{i=1,2}$  simultaneously.

**Example 2** *Let  $\varepsilon_i$  be normally and independently distributed with mean zero and variance .40.  $h(q) = 1$  for  $q \in Q = [-1, 1]$ . We then get  $(I_1^*, I_2^*, F_1^*, F_2^*, q_1^*, q_2^*) \approx (-\frac{3}{4}, 1, .08, .53, -.06, .21)$  with associated profits,  $\Pi_1^*(.) \approx .02$ ,  $\Pi_2^*(.) \approx .41$ .*

The profits of the upper certifier are much higher than the profit for the lower certifier, which creates incentives for the first entering certifier to choose a tough standard ( $I_2^* = 1$ ). The second entering certifier avoids stiff competition by choosing a soft standard  $I_1^*$ , in safe distance from the choice of  $I_2^*$ . Making other distributional assumptions would imply less extreme differences in profits. This simple example captures some of the dynamics of the market for business school degrees, where the oldest business schools have the most demanding standards, attract the most able students, charge the most presumptuous fees, and presumably makes the highest profits.

## 6 The market for auditing services

The theory outlined in the previous sections produced three main results. Certifiers offer a differentiated test standard, sellers with a higher unobservable quality self-select to a certifier with a tougher standard, and the certification fee paid by high-quality sellers to tough certifiers exceeds the fee paid by low-quality sellers to more lenient certifiers. In this section, I first review some of the accounting literature to evaluate the fit between the model and the markets for auditors. In the next section, I perform some independent

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<sup>19</sup>The case where the two certifiers choose  $I_i$  simultaneously would involve (symmetric) equilibria in mixed strategies in the choice of  $I_i$ , and are computationally very complex, but should lead to the same type of results.

analysis with data from the Norwegian market for auditors to make a finer assessment of the theory. Overall, these two sections suggest that the model applies in a natural manner to the market for auditing services.

At a basic level, "Auditors provide independent verification of manager-prepared financial statements, and can discover and report breaches in a client's accounting system." (Mansi et al., forthcoming, p.3), or in other words a clear certification role.<sup>20</sup> For example, auditors may reveal information about earnings management,<sup>21</sup> or may reveal information about the competence of the management team, and therefore affect the firm's perceived value.<sup>22</sup> Furthermore, the audit report system is discrete and simple, as in the model, and usually falls into a small number of categories depending on the seriousness of the accounting breaches.<sup>23</sup>

The supply side of the audit market for most Western countries can be classified into two segments, Big 5 auditors and non-Big 5 auditors (Hay et al., 2004), where Big 5 auditors are international businesses considerably larger than non-Big 5 auditors.<sup>24</sup> By their limited numbers, it does not seem unreasonable that one can think of Big 5 auditors as one when it comes to fee setting.<sup>25</sup> A similar argument applies to non-Big 5 auditor firms, which tend to be specialized in districts or regions. Interpreting the model literally, one can therefore think of it as capturing competition between the class of Big 5 auditors

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<sup>20</sup>Auditors do have other roles than informational, for example to provide insurance to investors as a way to indemnify their losses. The results of the empirical literature is mixed as to which of these two functions are more important (Mansi et al., 2001).

<sup>21</sup>By earnings management is meant that the firm manipulates the accounts by overstating gains or understating losses. This might be beneficial to the managers of the firm in order to obtain favorable conditions in the capital markets, or simply to boost the accounting-based part of the managers' pay. A considerable empirical literature finds evidence that firms are prone to engage in earnings management, in particular when they expect to report a loss otherwise, or they fall short of analysts expectations. For example, Burgstahler & Dichev (1997) reports that in their sample, "[...] 30-40% of the firms with slightly negative pre-managed earnings exercise discretion to report a slightly positive earnings."

<sup>22</sup>See Heal & Wahlen (2001) for a recent survey on the large body of empirical work on the interaction between disclosure, auditors, and firm value.

<sup>23</sup>In contrast to in the model, it is compulsory for a firm to have an auditor. The model can easily encompass this feature, and would yield the same predictions (for example, objects with quality  $q < q_1$  can be interpreted as not starting a business).

<sup>24</sup>The auditing market is after the demise of Arthur Andersen down at four big firms; KPMG, Coopers & Lybrand, PWC, and Ernst & Young. Since the main bulk of empirical investigations cited below cover the Big 5 era, we choose that label too.

<sup>25</sup>Fee collusion might come about via agreements that would not be covered by anti-trust law such as industry specialization. Dunne et al. (2002) provides evidence along these lines.

and the class of non-Big 5 auditors.<sup>26</sup>

A considerable bulk of the auditing literature simply takes it as given that Big 5 auditors are of higher quality than non Big-5 auditors, but without making it very precise what is meant by "auditor quality". One problem is that of measurement; whatever auditor quality is, it is hardly directly observable.<sup>27</sup> Consistent with the present theory, an early study by Nichols & Smith (1981) finds that switching from a large auditor (at that time Big 8) to a smaller one gives a negative stock market reaction, albeit a statistically insignificant one. Since auditor switch episodes are usually confounded by simultaneous events (Lys & Johnson, 1990), the more recent literature on auditor quality has focused on the market reactions to auditor choices in connection with debt or equity offerings. Several papers, including Toeh & Wong (1993), find that firms undertaking Initial Public Offerings choosing a Big 5 auditor get a more favorable offering price than firms choosing a non-Big 5 auditor. Mansi et al. (2004) reports a similar finding: firms choosing Big 5 auditor get cheaper debt financing (in particular firms with non-investment grade debt). It seems fair to say that the model can explain these empirical findings, in that one would expect that firms choosing a higher-quality (stricter) auditor to receives a more positive market reaction.

Turning to audit fees, starting with Simunic (1981) a large empirical literature which supports the notion that high-quality auditors (perceived as Big 5) charge more than lower quality auditors (perceived as non-Big 5). Typically these papers regress a measure of audit fees on explanatory variables such as audit complexity (e.g., firm size measured by sales turnover and the value of assets), audit risk (e.g., capital structure and industry dummies) and a dummy variable that captures whether a firm has chosen a Big 5 auditor. Across these empirical papers, the coefficient on the Big 5 dummy tend to be highly significant (Hay et al., 2004, finds that of 88 papers on audit fees about 60 of them report a significantly positive Big 5 coefficient).

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<sup>26</sup>The model does not exclude a case where there are more than two classes of auditors, but since the auditing literature tends to focus on two classes on auditors, it is more convenient to follow this convention.

<sup>27</sup>Ferguson et al. (2003) attempts a direct test of auditor quality. This paper finds empirical support for the notion that some auditors have better industry expertise than others, and charge higher audit fees. This is consistent with our arguments, since a certifier having a higher test standard plausibly would require a higher level of expertise.

Interestingly, although there is a strong notion in the accounting literature that fee differentials exist, there is a much less of a consensus on a theoretical underpinning (as an example, Hay et al. (2004) states that it is "... difficult to present a theoretical foundation for audit fee differences [...] "). DeAngelo (1981) suggests that larger auditors (read: Big 5) have incentives to perform a more thorough audit, due to greater reputational concerns (this is where Andersen got it wrong!). Although not phrased in terms of a formal model, this argument is suggestive of both a Big 5 premium and a positive market reaction to the choice of a Big 5 auditor due to reduced investor uncertainty (without involving any notion of private information). Closer to the current paper, Titman & Trueman (1986) constructs a separating equilibrium where high (low) quality auditors attract high (low) quality clients by a self-selection mechanism similar to in the present paper. While the present paper interprets a higher quality auditor as a more stringent auditor, in Titman & Trueman (1986) a higher quality auditor have a more precise test. However, since auditing fees are exogenous in the Titman-Trueman setting, it is not directly comparable to the current paper in that it does not deliver hypotheses on both auditor quality, self-selection of firms, and audit fees.<sup>28</sup>

To sum up, the accounting literature is supportive of several of the notions of the present theory, in particular that auditors fill a certification role, that there are differences in fees charged by different (classes of) auditors, and that different auditors have different quality. What is somewhat unclear, however, is whether the theory's notion of a higher quality auditor is the right one.<sup>29</sup> In particular, do firms choose auditors based on private information, as the present theory suggests, or do they pick auditor for other reasons such as reducing common uncertainty? To get closer to making an assessment on this question, in the next section I consider data from the Norwegian market for auditors.

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<sup>28</sup>If fees can be made endogenous in the Titman-Trueman model, and equilibria would exist that entail the segmentation of sellers, it would not be obvious how to empirically distinguish it from the theory of the present paper. Whether such a modification can be done is not obvious, as indicated in the Introduction.

<sup>29</sup>That the accounting field acknowledges a certain confusion on the notion of auditor quality is indicated by Hay et al. (2004), which states that "Future research should attempt to shed more insight into the issue of audit quality [...]". The Andersen-Enron scandal gives additional reasons to pursue models and evidence in this direction.

## 7 Testing the theory

If quality differences between auditors involves differences in degree of leniency between Big 5 and non-Big 5 auditors, as the theory suggests, then one would from the theory expect firms with bad unobservable characteristics at time  $t$  (known to the insiders of the firm such as management but unknown to the market) to be more prone to choose a non-Big 5 auditor at time  $t$ , since a firm with bad unobservable characteristics has more to gain from choosing a lenient auditor. A problem with this hypothesis, of course, is how to measure (value-relevant) firm characteristics that are unobservable. I propose a simple test procedure that attempts to get around this problem. The idea is that firm characteristics that are value-relevant at time  $t$ , but not observable, must sooner or later have observable effects on cash flows and earnings. For example, although Enron for a period of years overstated its earnings, there was a limit to how long it could do it.

My empirical strategy is therefore to estimate an empirical model of auditor choice that includes observable characteristics of the firm at time  $t$  and in addition includes variables that attempt to capture whether the firm drops "unexpectedly" in performance from time  $t$  to time  $t+1$ . Since there (at least to my knowledge) does not exist a consensus on which drops are more likely to be correlated with private information, I take a pragmatic stance and include a number of performance measures in the regressions.

More specifically, I estimate an equation of the following form,

$$Big5_i = \beta' X_{i,t} + \theta' \Delta_i + \epsilon_i \quad (14)$$

where  $Big5_i$  is a dummy variable equal to 1 if the firm has a Big5 auditor, and 0 otherwise.  $X_{i,t}$  is a vector of firm characteristics at time  $t$ , and  $\Delta_i$  is a vector describing the state of the firm at time  $t+1$  relative to at time  $t$ . I operationalize the  $\Delta$ -variable by letting it include various developments for firms, such as a change in sales, assets or equity, or a change in short term debt. Increases in the first three variables, and a decrease in the short term debt, is interpreted as a positive development for the firm.<sup>30</sup> To control for

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<sup>30</sup>While the justification for the first three measures are quite obvious, I include changes in short term debt, to capture the possibility that the firm becomes financially more constrained from  $t$  to  $t+1$ . In separate regressions, I also included drops in dividend. This gave the same type of results as reported

the fact that some firms may be in downward trends that are predictable by the market (one current example is the cigarette industry), I check the robustness of these results by including measures of firm performance in year  $t - 1$ .

To investigate whether there is a Big 5 premium in the Norwegian audit market, I also estimate an equation of the form,

$$Lfee_i = \gamma'X_{i,t} + \phi Big5_i + \tau_i \quad (15)$$

where  $Lfee$  is the log of auditor fees,  $X_{i,t}$  is a vector of firm characteristics and  $Big5_i$  is a dummy equal to 1 if the firm has a Big 5 auditor. Note that underlying this specification is the notion that the  $\Delta$ -vector does not affect audit fees at time  $t$ .

There is obviously some degree of freedom in picking the  $X_{i,t}$  vector. The standard explanatory variables for audit fee regressions can be classified into four categories (Hay, 2004); firm size and complexity, audit risk, and auditor characteristics such as quality and tenure. While firm size and complexity proxies for audit effort, audit risk captures the extent to which the auditor may be liable if the firm crashes. The meta-analysis of Hay (2004) reports that all these four variables tend to turn up significant in audit fee regressions across a large literature (where size explains about 70% of variation in audit fees).

There are several ways to operationalize these variables. To provide a regression on audit fee that is up-to-date and comparable to other studies, I use the specification of Chaney et al. (forthcoming), which analyzes audit fee determinants for a sample of U.K. firms in the period 1994-1998.<sup>31</sup> Their specification is,

$$\begin{aligned} Lfee_i = & \beta_1 + \beta_2 Big5_i + \beta_3 SIZE_i + \beta_4 Aturn_i + \beta_5 Curr_i + \beta_6 DA_i + \beta_7 Quick_i(16) \\ & + \beta_8 ROA_i + \beta_9 ROA_i * Loss_i + \beta_{10} Oslo\_dum_i + \beta_{11} Abs\_excep_i + \tau_i \end{aligned}$$

where:

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here.

<sup>31</sup>The only variable included in their analysis but skipped in the present is exports, which is not available in the Norwegian dataset.

<i>Lfee</i>	=	Logarithm of auditor's fee
<i>Big5</i>	=	1 if the firm chooses a Big 5 auditor, 0 otherwise
<i>Size</i>	=	Logarithm of total assets
<i>DA</i>	=	Long-term debt divided by total assets
<i>Cur</i>	=	Current assets divided by total assets
<i>Quick</i>	=	Current assets minus inventory divided by current liabilities
<i>Aturn</i>	=	Sales divided by total assets
<i>ROA</i>	=	Earnings before interest and taxes divided by total assets
<i>ROA * Loss</i>	=	ROA of the firm if the firm incurred a loss in 2000, 0 otherwise
<i>Abs_excep</i>	=	Absolute value extraordinary earnings items, divided by total assets

The variables *Size* and *Aturn* proxies for audit effort. The measures of financial structure and profitability are measures of audit risk. One would expect a higher ROA and a lower leverage to decrease audit risk, and therefore decrease audit fees. The *ROA\*Loss* variable captures that ROA presumably matters more for loss-making firms than for profitable firms. Quick ratio and leverage correspond to short-term and long-term financial structure, respectively. The reader is referred to Chaney et al. (forthcoming) for a closer justification of this choice of specification.

Let me now first describe the data, then investigate whether there is a Big 5 premium in the data, and then turn to auditor choice.

## 7.1 Data

The data is a three-year panel of Norwegian firms for the period 2000-2002. For each firm I have information on a range of yearly accounting measures, including auditing fees,<sup>32</sup> and the identity of each firm's auditor for the 2002 accounts.<sup>33</sup> Even if the data does not

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<sup>32</sup>The data also contains a consulting fee category. In principle, consulting services bought by one's auditor should be located in this category rather than in the category for accounting fees, but in practice the distinction can be hazy even for the firm itself.

<sup>33</sup>More specifically, I know auditor identity in January 2004. It is unlikely that there were more than a very marginal fraction that changed auditor in the 6 months period from July 31 2003 where the 2002 accounts were submitted to the tax authorities, until January 2004. However, knowing auditor identity at a particular point in time makes me unable to test for the effects of auditor tenure on auditing fees (e.g., Ghosh & Moon, 2003). Since I am primarily interested in explaining the choice of auditor, not auditing fees, tenure effects seem perhaps less important.

contain information on changes of auditor, it has the advantage of covering the aftermath of a period with relatively frequent shifts of auditors in the Norwegian market, the main reason being the strong position of Arthur Andersen prior to 2002, which audited about a fourth of the Norwegian larger firms prior to 2002.<sup>34</sup> The crisis in the Norwegian branch of Andersen, following the Enron and WorldCom scandals, led to Andersen Norway merging with Ernst & Young. Before and through this merger, Andersen lost a not insignificant fraction of their clients. Although the current data is not precise enough to pin down the exact fraction, it seems fair to say that Andersen clients had a genuine choice of changing auditor in this period since it was easy to attribute such a change to a need for a more stable environment rather than disagreements with the auditor or even worse an auditor-initiated termination of the relationship.

Sample selection. Again in line with Chaney et al. (forthcoming) I keep a firm in the sample only if it had annual sales above GBP 350K, and satisfies annual turnover in excess of GBP 750K, pre-tax profits greater than GBP 45K, or equity greater than GBP 750K. Further, I exclude firms with less than GBP 1 mill in total assets, since most variables are rounded to nearest thousand.<sup>35</sup> This gives about 7500 yearly observations.

## 7.2 Empirical results

Let me begin with a table of descriptive statistics, then describe the audit fee regressions, and finally the auditor choice regressions. All figures are for the year 2001 in NOK 1,000 unless stated otherwise (NOK 1,000 $\approx$ GBP 90).

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<sup>34</sup>According to interview with Erik Mamelund, CEO of Andersen Norway, with Dagens Naeringsliv (the main daily business oriented newspaper in Norway) in February 2002.

<sup>35</sup>Finally, commercial banks were excluded. This differs slightly from Chaney et al., which also excluded firms in the insurance industry. Since the Norwegian insurance industry is small and somewhat complicated to classify, I have kept it in the analysis.

**Table 1. Descriptive data (averages)**

	Total	Big 5 =1	Big 5=0
# Observations	7642	3959	3683
Log of Audit fees	4.06	4.289	3.803
Audit fees	95.09	128.93	58.467
Size (=log of total assets)	10.847	11.159	10.510
Total assets	392,804	694,821	66,009
Aturn (=Sales/Assets)	1.641	1.614	1.670
DA (Debt/Assets)	0.236	0.230	.242
Curr	0.582	0.579	0.585
Quick	1.792	2.131	1.427
ROA	0.077	0.065	0.090
Loss	0.167	0.199	0.132
Oslo_dum	0.238	0.235	0.225
Abs_excep	0.005	0.007	0.003
No employees	61.43	94.86	31.92
Share	100%	51.8%	48.2%

We see that Big 5 firms tend to be larger than non-Big 5 firms, but with a similar financial structure. Slightly above 50% of the sample are affiliated to a Big 5 auditor. Compared to UK firms, Norwegian firms are not unexpectedly smaller, and more highly leveraged.

I got the following results on audit fees.

**Table 2. Audit Fee OLS Regression Coefficients**

$n = 7408$	Coefficient	t value
Intercept	-1.165	-17.08
Big 5	.122	8.25
Size	.511	79.74
Aturn	-.141	-22.45
Curr	-.128	-3.84
DA	-.287	-7.52
Quick	-.001	-1.78
ROA	-.781	-13.30
ROA*Loss	-.128	-1.05
Oslo_dum	.221	13.04
Abs_excep	.219	1.63
Adj R-square	.526	

As expected, Size and the Oslo dummy comes out with positive coefficients. Somewhat surprisingly, however, both the measure of asset turnover and of liquidity are negative. The coefficient on the Big 5 dummy comes out positive at .122. This means that controlling for size, financial structure and complexity, firms that are audited by Big 5 auditors pay about 12% higher auditing fees. This is about two times the Big 5 premium estimated for the UK by Chaney et al. (forthcoming).<sup>36</sup>

Having established a likely Big 5 premium in the Norwegian market for auditors, let me now turn to investigate whether private information matters to the choice of auditor. The theory suggests that firms of lower quality (not directly observable to the market at time  $t$ ) are less likely to choose a Big 5 auditor at time  $t$  than firms of higher quality, controlling for firm characteristics. The variables I attempt to measure unobservable

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<sup>36</sup>The OLS model implicitly assumes that auditors are randomly allocated to client firms, which rationalizes the inclusion of Big5<sub>*i*</sub> as an exogenous variable in the regression. As pointed out by Chaney et al. (forthcoming), if there is self-selection in the sense that Big 5 firms are more complex, and Big 5 auditors better equipped to handle complexity, then the OLS estimate of  $\beta_2$  may be biased upwards. Given the magnitude of the estimated  $\beta_2$  (12%) it seems unlikely that self-selection can explain all of it.

attributes at time with  $t$  are changes in sales, equity, short debt, and assets between time  $t$  and time  $t + 1$ . The idea is simply that if a firm attempts to hide something unattractive about itself at time  $t$ , then one would expect it to pop up (at least partially) in a negative trend in those variables between time  $t$  and time  $t + 1$ . I therefore expect decreases in sales, equity, and assets, and an increase in the short debt, to be associated with a lower probability of choosing a Big 5 auditor.<sup>37</sup>

The null hypothesis is that there is no selection according to these "drop characteristics", controlling for the same observable characteristics as in the audit fee regression. The probit regression on auditor choice gave the following results.

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<sup>37</sup>To check whether these variables had other effects on the endogenous variables than on the choice of auditor, I performed auditor fee regressions for firms with and without a Big 5 auditor, respectively, adding them to the independent variables listed in Table 2. The results of these regressions indicate that there is a slight tendency within each such group of firms to pay higher auditing fees with improvements along these "unobservable" dimensions. This result could reflect quality differences also within the two groups of auditors. On the other hand, these findings were weak, as the explanatory power of the augmented regression was lower than the regression in Table 2.

**Table 3. Probit on choice of auditor**

$n = 7331$	Coefficient	Pr > t	Coefficient	Pr>t
Intercept	-3.46	0.000	-3.47	0.000
Size	0.380	0.000	0.375	0.000
Aturn	-0.157	0.000	-0.155	0.000
Curr	-0.308	0.000	-0.248	0.001
DA	-0.488	0.000	-0.368	0.000
Quick	0.018	0.000	0.012	0.002
ROA	-0.736	0.000	-0.721	0.000
ROA*Loss	0.209	0.507	-0.226	0.397
Oslo_dum	-0.090	0.016	-0.068	0.058
Abs_excep	0.681	0.038	0.880	0.007
Sales $\Delta$	0.031	0.222		
Equity $\Delta$	0.091	0.005		
Shortdebt $\Delta$	-0.037	0.240		
Assets $\Delta$	0.018	0.794		
Pseudo R-square	0.080		0.076	
Log likelihood	-4669		-4884	

The first regression is the main content of the section. It attempts to measure the effect of unobservable heterogeneity at time  $t$  on the probability of choosing a Big 5 auditor at time  $t$ , controlling observable characteristics of the firm. The reports reported are in logs. For example,  $Sales\Delta = \ln(\frac{Sales02}{Sales01})$ .<sup>38</sup> The coefficient on the Equity $\Delta$  variable is statistically significant at the 1% level while the Sales $\Delta$  and Shortdebt $\Delta$  coefficients are of the right sign and not far from being significant. The Assets $\Delta$  coefficient has the right sign but is far from being significant. A test of the  $\Delta$  coefficients being jointly equal to zero is rejected at 0,25% level. I also performed regressions where only one of the  $\Delta$ -

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<sup>38</sup>The results without logs were qualitatively the same but with a lower R<sup>2</sup>. The descriptive statistics for the variables are,

variables were included at the time. This did not affect the results in a qualitative manner. These results suggest that unobservable characteristics at time  $t$  (private information, or correlates of it) affect auditor choice in a manner outlined by the theory.

Since the  $\text{Equity}\Delta$  variable gives the clearest results, we should note that changes in equity can be due to two factors, the after-tax profit increment in 2002 (subtracted dividends) and through increased base equity. Further analysis of the data suggests that mainly the latter mechanism drives the results. Since the vast majority of firms in the sample are not publicly listed, increases in base equity will likely be from existing investors willing to put more of their funds in the company, consistent with favorable information about the firm's prospects. This justifies using the  $\text{Equity}\Delta$  variable as one way of capturing private information.<sup>39</sup>

One possible explanation of the results is that firms audited by Big 5 for some exogenous reason had a bad year in 2002. I therefore redid the full analysis for the 2000-2001 period. The results were remarkably similar to the 2001-2002 period, except  $\text{Sales}\Delta$  turned out significant in addition to  $\text{Equity}\Delta$ .<sup>40</sup>

Let me discuss functional forms. The log-specification dampens the effect of positive outliers (firms with a high  $\Delta$ ) but creates negative outliers of firms with  $\Delta$ -s close to 0. I therefore ran the same regressions again, by defining  $\text{Variable}\Delta = \frac{\text{Value02}}{\text{Value01}}$  and  $\text{Variable}\Delta = \sqrt{\frac{\text{Value02}}{\text{Value01}}}$ . These regressions gave slightly lower  $R^2$  values but the same overall picture.<sup>41</sup> The results also seem very robust to various attempts to control for the

	Total	Big 5 =1	Big 5=0
# observations	7642	3959	3683
$\ln(\text{Sales}\Delta)$	-0.010	-0.074	-0.082
$\ln(\text{Equity}\Delta)$	-0.069	-0.041	-0.100
$\ln(\text{Shortdebt}\Delta)$	-0.010	-0.023	-0.082
$\ln(\text{Assets}\Delta)$	-0.032	-0.038	-0.025
$\text{Dividend}\Delta, n = 3251$	2.326	2.319	2.330

<sup>39</sup>With bad future prospects, the investors should be more eager to increase debt levels. This argument may sound like contradicting the pecking-order theory, but recall that the increases in equity base is due to investments by inside equity holders.

<sup>40</sup>In the log regressions, both  $\text{Sales}\Delta$  and  $\text{Equity}\Delta$  came out significant at the 0,000 level. The coefficient estimates were of similar magnitude both for the  $\Delta$ -variables and for the controls.

<sup>41</sup>For the first specification, all the coefficients were of the right sign.  $\text{Assets}\Delta$  came out significant at the 1% level, while all coefficients being zero is rejected at the 0,9% level. In the  $\sqrt{\quad}$  specification,  $\text{Equity}\Delta$  again came out significant, and only  $\text{Debt}\Delta$  came out with the wrong sign, but insignificantly so. All

effects of outliers. The most illustrative of these experiments is perhaps the following non-parametric test. I grouped the dataset into two subgroups according to whether a firm had a Big 5 auditor or not, and then looked at whether there were significant differences in the  $\Delta$ -s between these two groups, by a test of whether the median  $\Delta$ 's were the same. All the four test statistics constructed in this manner, one for each of the  $\Delta$ 's turned out with the right sign, with  $p$ -values for one-sided tests equal to 0.7% (Sales $\Delta$ ), 0.0% (Equity $\Delta$ ), 100% (Assetsdrop $\Delta$ ), and 3.7% (Shortdebt $\Delta$ ).<sup>42</sup> In addition, I excluded from the sample firms with  $\Delta$ -values that indicated great changes from 2001 to 2002 occurred (which might indicate mergers or closures); the results were again qualitatively the same. All in all, these exercises indicate that the choice of functional form or outliers do not drive the results reported in Table 3.<sup>43</sup>

It is hard to know the extent to which changes between time  $t$  and time  $t + 1$  are unexpected at time  $t$ . To control for the fact that some firms may be into a predictable trend (and that this for some reason is correlated with the choice of a non-Big 5 auditor; for example the Big 5 may refuse to deal with firms in a downward spiral due to possible future suits from investors or providers of inputs), I included profits before taxes in 2000 as an additional control. Although this control turned out with a significantly positive effect on the probability of choosing a Big 5 auditor, it had only a small effect on the  $\Delta$ -coefficients in Table 3.<sup>44</sup>

These results could conceivably be due to some peculiarities of the Norwegian institutional environment. I therefore ran a regression replicating Chaney et al. (forthcoming).

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coefficient being equal to zero was rejected at the 10% level.

<sup>42</sup>In these tests I also included a measure of development in dividend payments, measured as  $\text{Dividend}\Delta = \frac{\text{Dividends}_{2002}}{\text{Dividends}_{2001}}$  (because a significant fraction of firms paid a zero dividend in both years, or in 2001 only, this variable is less suitable to a standard regression analysis). This analysis also gave the right sign, but at a statistically insignificant level.

<sup>43</sup>As an alternative measure of unobserved heterogeneity, I performed the same type of regressions by replacing the  $\Delta$ 's with return on equity, defined as  $\frac{\text{profit before taxes year } t}{\text{equity at the end of year } t-1}$ . This specification gave the right sign for the 2000-2001 regressions, but the wrong sign for the 2001-2002 regressions (in neither case significant). Since a firm performing badly in the beginning of year  $t$  will in effect have a lower denominator for the rest of the year, this specification seems less robust than the  $\Delta$ 's, but does suggest the need to refine the tests of private information outlined here.

<sup>44</sup>A related point goes as follows. If the drops are highly correlated, there is arguably less scope for private information since, informally speaking, the market knows all if it knows something. The following table gives an indication of correlation patterns.

**Table 4. Spearman rank correlations**

The results of this regression is reported in the second column. Although the leverage coefficient is significantly different (this may be related to the fact that UK has a more equity based system for financing than Norway) the coefficient estimates are overall similar to that in Chaney et al. (forthcoming).

To this point, I have followed the convention of the accounting literature and grouped auditors into Big 5 auditors and non-Big 5 auditors, with the underlying assumption that Big 5 auditors are stricter than non-Big 5 auditors. As a complement to this analysis, I now take a more pragmatic stance on which auditors are of high quality, and investigate whether paying a higher audit fee at time  $t$  is correlated with positive developments between time  $t$  and time  $t + 1$ . If this is so, it is taken as further corroboration of the model.

	Sales $\Delta$	Equity $\Delta$	Shortdebt $\Delta$	Assets $\Delta$	Big5
Sales $\Delta$	1				
Equity $\Delta$	0,18	1			
Shortdebt $\Delta$	0,27	0,13	1		
Assets $\Delta$	0,38	0,30	0,57	1	
Big5					

Table 4 indicates that all four drop variables have the raw correlation predicted by the theory. that Sales $\Delta$  and Equity $\Delta$  capture different aspects of the firm's development, while Assets $\Delta$  is unlikely to capture an independent aspect given the high correlations with the other variables. Also, the table makes one question the interpretation of short term debt increases as a negative event, since it is positively correlated with the other variables. This should perhaps not come as a surprise, since a firm in growth is likely to experience an increase in short term debt. As a consequence of this finding, I redid the regressions from Table 3, but dropping Shortdebt $\Delta$  and Assets $\Delta$  from the variable list. The resulting coefficients on Sales $\Delta$  and Equity $\Delta$  come out with right sign, and Equity $\Delta$  more significant than before. The coefficient estimate on Equity $\Delta$  ( $p$  value in paranthesis) become 0.102 (0.000) and on Sales $\Delta$  became 0,020 (0.437). Overall, therefore, it seems that there are more than one dimension to unobservable characteristics, which pegs under the notion of private information being likely present.

**Table 4. Audit fees versus private information**

$n = 7638$	Coefficient	Pr > t	Coefficient	Pr>t
Intercept	-1.295	0.000	-1.211	0.000
Size	.526	0.000	.521	0.000
Aturn	-.142	0.000	-.138	0.000
Curr	-.079	0.002	-.130	0.000
DA	-.255	0.000	-.266	0.000
Quick	-.000	0.300	-.001	0.129
ROA	-.843	0.000	-.847	0.000
ROA*Loss	-.107	0.412	-.024	.827
Oslo_dum	.233	0.000	.230	0.000
Abs_excep	.337	0.013	.255	0.051
Sales $\Delta$	.105	0.000		
Equity $\Delta$	.021	0.094		
Assets $\Delta$	-.028	0.219		
R-square adj	.529		.514	

The first regression attempts to test whether firms that pay a higher auditing fee in the year 2001 improves its performance from 2001 to 2002, controlling for the same type of firm characteristics as in the previous regressions (without including a Big 5 dummy anywhere in the regression). The results indicate that firms that pay a higher auditing fee in 2001 have a more positive development from 2001 to 2002 both with respect to changes in sales and to changes in equity. The coefficient on Sales $\Delta$  is highly significant ( $t$  value of 10.8) and the Equity $\Delta$  coefficient is significant at the 10% level. The coefficient on Assets $\Delta$  is of the wrong sign, but insignificantly so.<sup>45</sup> Running a regression with only Asset $\Delta$  gives a positive coefficient significant at the 0.000 level ( $t$  value of

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<sup>45</sup>In line with the auditor choice regressions, as an alternative specification of future performance, I also ran regressions with return on equity in 2002 instead of the  $\Delta$  variables. The coefficient on 2002 returns has a positive but insignificant sign.

5.49). A test of the  $\Delta$  coefficients being jointly zero is rejected at the 0.000 level. The empirical results from regressing auditing fees directly on observable and unobservable firm characteristics therefore confirms the picture from the previous regressions. Overall, therefore, the empirical results suggest that unobservable characteristics at time  $t$  (private information, or correlates of it) affect auditor choice and audit fees in a manner outlined by the theory.

## 8 Conclusion

The paper has proposed a simple theory of oligopolistic certification based on the notion that certifiers differ in test strictness; it may be easier to obtain a pass grade from some certifiers than from others. From the theory, we obtained two main results. First, that sellers are segmented across certifiers according to their underlying quality; higher quality sellers choose stricter certifiers. Second, the theory gave a clear-cut prediction on equilibrium fee-setting: certifiers attracting sellers of higher quality will charge a higher fee than certifiers attracting sellers of lower quality. The second finding should be contrasted with signaling models such as Guasch & Weiss (1981) and Titman & Trueman (1986), which obtains segmented equilibria but by imposing an exogenous fee structure.

The second part of the paper attempted to assess the empirical validity of the theory in the context of the market for auditing services. It was first argued that the theory can explain stylized facts on auditor choice and auditor fees that are not straightforward to explain for existing theory. Second, our empirical investigation of Norwegian data gave support to the theory's notion that private, asymmetric information may be important in the determination of auditor choice and audit fees.

## 9 Appendix

First  $U(\textit{pass})$  and  $U(\textit{fail})$  are derived. Recall that in general,  $E(q|A) = \frac{\int_A g_A(q)q dq}{\text{Pr ob}(A)}$  where  $g_A(\cdot)$  is the conditional density function and  $A$  is some event. By the law of large numbers, the fraction of sellers with quality  $q$  that passes the test is deterministic and equals  $\text{Pr}(\textit{pass}|q, I)$ . The conditional density, i.e., the density of those that pass, is just

equal to this entity, and the probability of passing test  $I$  for a random seller on  $[q_1, q_2]$  equals  $\int_{q_1}^{q_2} \Pr(\text{pass}|q, I)dq$ .<sup>46</sup> Hence we have that,

$$\begin{aligned} U(\text{pass}) &= \frac{\int_{q_1}^{q_2} \Pr(\text{pass}|q, I)qdq}{\int_{q_1}^{q_2} \Pr(\text{pass}|q, I)dq} \\ U(\text{fail}) &= \frac{\int_{q_1}^{q_2} \Pr(\text{fail}|q, I)qdq}{\int_{q_1}^{q_2} \Pr(\text{fail}|q, I)dq} \end{aligned} \quad (\text{A1})$$

For an agent with ability  $q$  who attends a certifier whose customers lie on the interval  $[q_1, q_2]$  we can therefore write,

$$U(q; q_1, q_2) = \Pr(\text{pass}|q, I) \frac{\int_{q_1}^{q_2} \Pr(\text{pass}|q, I)qdq}{\int_{q_1}^{q_2} \Pr(\text{pass}|q, I)dq} + \Pr(\text{fail}|q, I) \frac{\int_{q_1}^{q_2} \Pr(\text{fail}|q, I)qdq}{\int_{q_1}^{q_2} \Pr(\text{fail}|q, I)dq} - F \quad (\text{A2})$$

Let me now consider the pricing game in a **duopoly**. The profits are,

$$\begin{aligned} \Pi_1 &= F_1(q_2 - q_1) \\ \Pi_2 &= F_2(1 - q_2) \end{aligned} \quad (\text{A3})$$

For the lower cutoff  $q_1$  we have the same condition as in the monopoly case,

$$\Psi_1(F_1, F_2, q_1, q_2) = UU_1(q_1; q_1, q_2) - F_1 = 0 \quad (\text{A4})$$

For the upper cutoff  $q_2$  we have the condition,

$$\Psi_2(F_1, F_2, q_1, q_2) = UU_2(q_2; q_2) - F_2 - UU_1(q_2; q_1, q_2) + F_1 = 0 \quad (\text{A5})$$

The first order conditions for profit maximization are,

$$\begin{aligned} \frac{d\Pi_1}{dF_1} &= q_2 - q_1 + \left( \frac{\partial q_2}{\partial F_1} - \frac{\partial q_1}{\partial F_1} \right) F_1 = 0 \\ \frac{d\Pi_2}{dF_2} &= 1 - q_2 - \frac{\partial q_2}{\partial F_2} F_2 = 0 \end{aligned} \quad (\text{A6})$$

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<sup>46</sup>For notational convenience, I assume that  $q$  is uniformly distributed, so that the  $h(q)$  terms cancel.

I use the implicit function theorem to determine  $\frac{\partial q_1}{\partial F_1}$  as,

$$\frac{\partial q_1}{\partial F_1} = -\frac{\Psi_{1F_1}}{\Psi_{1q_1}} = \frac{1}{\Psi_{1q_1}} \quad (\text{A7})$$

and,

$$\begin{aligned} \frac{\partial q_2}{\partial F_1} &= -\frac{\Psi_{2F_1}}{\Psi_{2q_2}} = -\frac{1}{\Psi_{2q_2}} \\ \frac{\partial q_2}{\partial F_2} &= -\frac{\Psi_{2F_2}}{\Psi_{2q_2}} = \frac{1}{\Psi_{2q_2}} \end{aligned} \quad (\text{A8})$$

We then have the following four equations determining the four endogenous variables  $(F_1^*, F_2^*, q_1^*, q_2^*)$ ,

$$\frac{d\Pi_1}{dF_1} = q_2 - q_1 - F_1 \left[ \frac{1}{\Psi_{2q_1}} + \frac{1}{\Psi_{1q_2}} \right] = 0 \quad (\text{A9})$$

$$\frac{d\Pi_2}{dF_2} = 1 - q_1 + \frac{F_2}{\Psi_{2q_2}} = 0$$

$$\Psi_1(F_1^*, F_2^*, q_1, q_2) = 0$$

$$\Psi_2(F_1^*, F_2^*, q_1, q_2) = 0$$

For certifier 2 the second order condition for optimum equals,

$$\frac{\partial^2 \Pi_2}{\partial F_2^2} = \frac{1}{\Psi_{2q_2}} \left[ F_2 \frac{\Psi_{2q_2q_2}}{\Psi_{2q_2}^2} - 2 \right] = \frac{1}{\Psi_{2q_2}} \left[ (1 - q_2) \Psi_{2q_2} \frac{\Psi_{2q_2q_2}}{\Psi_{2q_2}^2} - 2 \right] = \frac{1}{\Psi_{2q_2}} \left[ (1 - q_1) \frac{\Psi_{2q_2q_2}}{\Psi_{2q_2}} - 2 \right] < 0 \quad (\text{A10})$$

For certifier 1, the SOC is slightly more involved,

$$\begin{aligned} \frac{\partial^2 \Pi_1}{\partial F_1^2} &= \frac{\partial q_2}{\partial F_1} - \frac{\partial q_2}{\partial F_1} - \frac{1}{\Psi_{1q_1}} - \frac{1}{\Psi_{2q_2}} + \frac{\partial q_1}{\partial F_1} F_1 \frac{\Psi_{2q_1q_1}}{\Psi_{2q_1}^2} + \frac{\partial q_2}{\partial F_1} F_1 \frac{\Psi_{1q_2q_2}}{\Psi_{1q_2}^2}. \\ &= -2 \left[ \frac{1}{\Psi_{1q_1}} + \frac{1}{\Psi_{2q_2}} \right] - (1 - q) (\Psi_{2q_1} + \Psi_{1q_2}) \frac{\Psi_{2q_1q_1}}{\Psi_{2q_1}^3} - (1 - q) (\Psi_{2q_1} + \Psi_{1q_2}) \frac{\Psi_{1q_2q_2}}{\Psi_{1q_2}^3} \end{aligned} \quad (\text{A11})$$

In the numerical analysis, (A9) was used to compute equilibria, and the second order conditions (A10) and (A11) were confirmed to hold.

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