Free-Entry Equilibrium in a Market for Certifiers*

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Abstract

The role of certifiers is to test products for quality, and to communicate the test results to the market. We construct a free-entry model of certification, where each certifier chooses a test standard and a price for certification. In equilibrium, certifiers differentiate their test standards, and attract different segments of the market. The price for having certified a high-quality product is higher than the price for having certified a low-quality product, and the net gain from being certified increases in product quality. We test and find support for these predictions in the market for MBA education, and also discuss how to apply the model to questions of regulation and minimum quality standards.

1 Introduction

It is well known that asymmetries of information can hinder trade that otherwise would be beneficial for all trading parties. To offset negative effects from asymmetries of information, different institutions can emerge. One example is warranties; if contracts can

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be written such that sellers of low-quality products are punished, such 'lemons' will subtracted from the market, and a more efficient level of trade can be realized. A different institution that can faciliate trade, particularly when contracts are difficult to write or to enforce, due to e.g., limited liability, is certification. Certifiers are third parties in the trading process with the ability to separate lemons from non-lemons before trade takes place. Certifiers, equipped with such assessment abilities, and a reputation for truth-telling, can make a business by refusing to certify lemons.

The real world abounds with examples of institutions that has certification as the main function, or an important function. For example, auditors assess whether the accounting practices of firms comply with GAAP (generally accepted accounting principles), investment banks evaluate the quality of firms that want to raise capital, credit ranking agencies assess the credit-worthiness of firms, scientific journals accept or reject papers based on assessments of scientific quality, and universities admit and grade students according to their academic achievement and potential.

A common characteristic of certification markets is that different certifiers serve different segments of the market. For example, it is well known from the auditing industry that the 'Big 5' mainly attract high quality firms. Journals of higher rank generally publish papers of higher quality than lower rank journals, and top-ranked universities admit entry and award degrees to students of higher average ability than universities of lower rank.

The segmentation in certifying markets implies that the value of a certificate can be highly dependent on which certifier issued it: A firm's value will be higher if Arthur Andersen finds its accounting practices in line with GAAP than if some provincial auditing firm had formed the same conclusion, the value of a publication in Econometrica is higher than the value of a publication in lower-ranked journals, a student's job market prospects is better if he receives an MBA degree from Harvard than from most other universities, and, for marine vessels, a certificate from Lloyds or Veritas is a stronger indication of high quality (e.g., low risk of making environmental damage) than a certificate from one of the smaller agencies.

The purpose of the paper is to propose a theory of certification with multiple certifiers, where different certifiers capture different segments of the market in equilibrium. We wish to develop the implications for price setting and for surplus division of this theory, and to confront these implications with data. Finally, we wish to discuss how the theory can be applied to issues of public policy.

In the stylized model, there are three types of agents; sellers, buyers, and certifiers. Initially, only sellers know product quality. Certifiers decide whether to enter the market, and if they do, choose which segment of the market to target their (costly) test for, and a price to charge for testing. Test targeting takes the form of test specialization. One possible test specialization is to build expertise on separating high quality products, and a different possible specialization is to build expertise on separating low quality products. Specifically, each certifier chooses a cutoff, enabling it to distinguish objects to the left of the cutoff from objects to the right of the cutoff. Sellers then decide whether to be certified, and which certifier to attend to. Tests are then performed, the test results made public, and finally buyers bid for all objects conditional on the test results.

The equilibrium we focus on has several attractive properties. First, certifiers offer differentiated tests; some certifiers attempt to attract high-quality sellers, by setting a high cutoff, while other certifiers attempt to attract low-quality sellers, by setting a low cutoff. Correspondingly, high (low) quality sellers will attend to the high (low) cutoff certifiers. Second, the prices charged for certification (one for each certifier) is increasing in the location of a certifier: if a certifier offers a test with a higher cutoff than another certifier, the first certifier will charge a higher price for certification than the other certifier in equilibrium. The intuition for this result is that sellers at the high-end of the quality scale are willing to pay more to be certified than sellers at the low end of the quality scale. Third, the distribution of certifiers in equilibrium will be asymmetric; there will be a higher frequency of certifiers in the high-quality end of the market than in the low quality end. Also this result reflects the fact that there is higher willingness to pay for being certified in the high end of the market. Fourth, the net surplus from being certified, taking into account both the cost and the value added from certification, increases in the true value of a seller's object. This result follows from a type of reasoning common in models of signaling; a higher type can mimic a lower type and get at least as high payoff in equilibrium. This result points to an intimate relation between certification and signaling, a relation that will be commented upon further in the text.

While the result on the asymmetry in the distribution of certifiers rests upon assumptions made on cost structure and upon distributional assumptions, the second (price monotonicity) and the third property (net surplus monotonicity) of equilibrium are independent of such assumptions. They are therefore natural candidates for testing of the theory. We perform such a test of the theory with data from the market for MBA education.

The free entry assumption of the model ensures that all certifiers will make zero profits. Moreover, the constructed equilibrium has the feature that seller surplus will be low, and hence total welfare will tend to be low. In the extension of this negative result, we discuss the role of public policy that aims at restricting the number of active certifiers in the market.

An early paper, Laffont (1975), considers the possibility that third parties can mitigate lemons problems, but in a non-strategic setting. Laffont (1975) also introduces the possibility that such experts may harm welfare, for the same type of reason as in the present paper. More closely related is the literature on strategic certification.[1] Biglaiser (1993) considers a setting where products are either of low or of high quality, and discusses the incentive to become a (monopoly) certifier in such a market. However, in Biglaiser (1993) there is no threat of entry, and moreover there is no choice over test standard. Lizzeri (1999) focuses on a setting with a monopoly certifier, who can test products perfectly, without any cost, and without a threat of entry. The main result is that such a certifier maximizes profits by revealing as little information as possible about the objects that are certified. As we shall see later, we can obtain the same type of non-revelation result in our setting, but only in a special case.

The plan of the paper goes as follows. In Section 2, we set up the model. In Section 3, we derive the main results on market structure. In Section 4 we test the two main hypotheses of the paper with data from the MBA market, and in Section 5 we discuss

[1] Broecker (1990) considers an adverse selection model of a credit market, where fund-raising entrepeneurs shop banks to get the best deal. Before offering a loan, banks test entrepeneurs for creditworthiness. However, the result of the test is not made public in the market, and neither are tests differentiated.

In the literature on disclosure of private information, starting with Grossman (1981), it is assumed that the trading parties can make verifiable statements about product quality while, in contrast, we focus on the incentives to acquire verifiable statements through intermediaries, and the endogenous informational content of these statements.

welfare and public policy issues. Section 6 concludes. Some proofs are relegated to Appendices A and B.

2 The Model

There are three types of agents; sellers, buyers, and certifiers. Each seller is endowed with an object of value x to each buyer, where $x \in [0, 1]$. Each seller has valuation 0 of his object. The distribution of objects follows the (differentiable) cumulative frequency function $G(x)$, which is assumed to have uniform density $g(x) = 1$. Each seller knows the value of his object to the buyers, but absent of any information the buyers are ignorant about x, except knowing $G(x)$.

Certifiers test objects and get information about their value. We assume that each certifier sets a cutoff $I_k \in \Re$, which makes it able to (perfectly) distinguish objects with value x less than I_k from objects with value x greater than I_k.[2] Later, we consider the possibility of noisy tests. For simplicity, we let the cost of certification consist of a fixed cost $F > 0$ for rigging the test, and marginal cost equal to zero. Later, we will discuss the impact made by these assumptions.

There are N ex-ante identical certifiers that can enter the market, where N is large. It is convenient to separate entry into two stages, stage 1 and stage 2. At stage 1, n certifiers enter the market sequentially, incur the fixed cost F each, and fix an I_k and a price to charge for certification P_k, where $k \in \{1, .., n\}$.[3] At stage 2, potential entrants (of which there are many) observe the sequences $\{I_k\}$ and $\{P_k\}$, and decide whether to enter or not. If the first potential entrant decides to go into the market, it chooses a cutoff and a price, which is observed by the next potential entrant, which then decides whether to enter, and so on. At stage 3, sellers observe $\{I_k\}$ and $\{P_k\}$, and choose whether to

[2]The assumption that each certifier sets one cutoff each seems to be a good approximation to what goes on in several important certifying markets, as the market for auditing reports, MBA degrees, driving licenses, and marine vessel certification, since the test results of each certifier in these markets are typically of a simple binary character (GAAP standard or not, admit or not, fail or pass). The test structure needs to be modified to fit the reports given by investment banks and for credit ranking agencies (like Moody's), whose reports are somewhat more elaborate. A question we do not pursue is why certifier reports typically only reveal such coarse information. Perhaps one explanation is that a finer information structure makes cheating on one's reputation too lucrative.

[3]Certifers are assumed to being unable to charge a price conditional on the test result.

be certified or not, and which certifier to attend to. At stage 4, tests are performed and the results made public. At stage 5, the buyers engage in a first-price sealed-bid auction over the objects (mimicking a competitive market). The equilibrium notion is sequential equilibrium.

3 Results

In this section, we first derive the equilibrium we focus on, and then discuss the robustness and uniqueness properties of the equilibrium.

3.1 Equilibrium

Let n be the equilibrium number of active certifiers. Label the cutoffs chosen in equilibrium such that $I_1 \leq ... \leq I_k \leq ... \leq I_n$, and denote the cutoff set by the certifier of rank k by I_k , and its price for certification by P_k. Furthermore, let $\lfloor y \rfloor$ be the integer closest to y from below, where $y \in \Re$. We then have the following.

Proposition 1 *There is an equilibrium with the following properties:*

- *The number of entering certifiers equals* $\left\lfloor \frac{1}{2F} \right\rfloor$.
- $I_1 < ... < I_k < ... < I_n$.
- *The price a certifier charges for certification is increasing in his rank* k.
- *The frequency of certifiers is increasing along the unit interval.*

Proof. We prove the result assuming that $\frac{1}{2F} \in \{1, 2, 3, ...\}$, and consider the general case in Appendix A. First notice that if certifier k attracts the sellers on the interval $[a_k, b_k]$ and charges price P_k, his profits are,

$$\Pi_k(I_k, P_k; ., .) = P_k(b_k - a_k) - F \tag{1}$$

For the proposed equilibrium, begin with the certifier at the top end of the scale, and denote his strategy for (I_n, P_n). Suppose that for a given I_n, the top certifier sets $P_n =$

$\frac{(I_n+1)}{2}$, and attracts all the sellers on the interval $[I_n,\ 1]$. Since there is a threat of entry, it is necessary for equilibrium that this certifier make profit equal to zero, which implies that $I_n = \sqrt{1-2F}$. Now move on to certifier $n-1$. By the same argument, it can be seen that setting $I_{n-1} = \sqrt{1-4F}$ and take all the seller's surplus, by setting $P_{n-1} = \frac{(I_{n-1}+I_n)}{2}$, yields zero profits. In this manner, we generate the sequence with typical element $I_k = \sqrt{1-2(n+1-k)F}$, where $k \in \{1,2,...,n\}$, which by using $n = \frac{1}{2F}$ simplifies to

$$I_k = \sqrt{2F}\sqrt{k-1}. \tag{2}$$

The end of the sequence occurs for the certifier who sets $I_1 = \sqrt{1-\frac{2F}{2F}} = 0$. All sellers make zero surplus. Substituting (2) into $P_k = \frac{(I_k+I_{k+1})}{2}$, we obtain

$$P_k = \frac{\sqrt{2F(k-1)}+\sqrt{2Fk}}{2}. \tag{3}$$

From (3), it follows that prices are increasing in the rank of the certifier. To show that the frequency of certifiers is increasing along the unit line follows from (2). It follows from the construction that all entering certifiers make zero profits. The beliefs of the sellers that support the equilibrium is that by choosing not to be certified, or by failing to pass a certification test, buyers will think they are of the worst possible type (0). Given these beliefs, which are not contradicted along the equilibrium path, the sellers (weakly) prefer to be certified at the certifier with the cutoff closest to the left of the value of their product. The beliefs of the entering certifiers that support the equilibrium (which is not contradicted on the equilibrium path) is that by following the equilibrium strategy there will be no entry, and hence zero profits, while by deviating to attempt to make positive profits, there will be entry of one of the potential entrants ensuring *negative* profits for the deviant. We now construct sequentially rational strategies for the potential entrants that is consistent with those beliefs. Suppose that entrant i plays the following entry strategy: enter if and only if one of the existing certifiers (including those that may have entered before at stage 3) make a positive profit (it is easy to verify that if this condition holds, the entrant can make non-negative profits from entering). More specifically, suppose that the certifier making a positive profit is the deviator from the proposed equilibrium. Denote the cutoff of the certifier that makes a profit, the deviator, by I_D and its price by P_D, and the corresponding choice for the entrant for I_E and P_E. Furthermore suppose that the first entrant sets $I_E = I_D$ and $P_E = P_D - \delta$, where $\delta > 0$ is set to ensure zero profits for the entrant. Since nobody makes positive profits after the entry of the first entrant, there will be no more entry, given that the proposed strategy is played. Moreover, it is simple to check that the deviator must make a negative profit. Hence under the proposed equilibrium strategy, and beliefs about off-equilibrium path behavior of entrants, none of the n certifiers that enter at stage 2 will have an incentive to deviate. Now consider deviation by one of the potential entrants. Clearly a deviation that ensures negative profits makes no sense, since there will be no additional entry. Now consider a deviation that gives positive profits. Analogously to the case above, after a deviation that gives positive profits to the entrant, there will be entry of the next potential entrant, and then no more entry, resulting in a negative profits to the deviating entrant. Hence the proposed equilibrium is indeed an equilibrium. ■

In equilibrium, certifiers differentiate their tests by choosing different cutoffs, and each certifier captures the sellers between his own cutoff and the cutoff of the certifier of immediate higher rank. Since the test is deterministic, no sellers fail their chosen certification test, and it follows that sellers tested by a higher-ranked certifier will enjoy a higher increase in market value through certification than sellers attending a lower certifier. Prices increase in certifier rank because sellers with a high object quality have a higher willingness to pay for being tested than sellers with a low product quality. Hence the higher increase in market value from being certified by a higher-ranked certifier is offset by a higher price paid for certification, a point we elaborate on in the welfare section.

Certifiers distribute themselves with increasing proximity as we move up along the unit line, because for a given interval length, it is more lucrative to certify a group of sellers at the top of the unit line than at the bottom. Hence, there must be more certifiers at the top than at the bottom of the interval, relative to the underlying distribution of projects.[4]

It is plausible that the fixed costs associated with rigging a test is an increasing function of the location of the cutoff. Such an increasing function could reflect that separating high-quality products requires a more complex test technology than separating low-quality products.[5] We should therefore notice, therefore that while the first and the fourth part of Proposition 1 rest on the particular shape of $F(.)$, the more important second and third part of Proposition 1 do not rely on this assumption. In particular, we do not rely on this assumption for obtaining price monotonicity, the result we later will attempt to test with data from the MBA market. Likewise, the results that will be tested are robust to the introduction of positive marginal costs of certification, since in the constructed equilibrium such marginal costs will only affect the size of the interval certified necessary to make zero profit, not price monotonicity.[6]

The role of the prices being fixed at stage 1 is to ensure the existence of equilibria, for the following reason. In equilibrium, some sellers must be indifferent as to which certifier to attend to. If prices are fully flexible this condition cannot hold, since the bottom certifier (think of two neighboring certifiers) can get a discontinuous jump in customer base by lowering the price for certification by a small amount.[7] Since it is not obvious which mechanisms prohibit certifiers to adjust their prices relatively rapidly (one could be reputation effects), we remark that the equilibrium obtained in Proposition 1 can also be derived in a repeated version of the game, where n and $\{I_k\}$ is determined first, and then a collusive agreement is (implicitly or explicitly) formed between the n entering certifiers

[4] The market for auditors seems at odds with the first and the fourth part of Proposition 1, since all the Big 5 specialize in the upper end of the market. This phenomenon can be made consistent with Proposition 1 by assuming that the distribution of projects is skewed to the right, rather than being uniform (or, less likely, F is lower for a higher cutoff). Or it could be that the Big 5 avoid competition by specializing in different geographical regions (see Dunne et al., 2000, for such evidence).

[5] Or it could reflect that the cost of establishing a reputation of truth-telling is higher for a higher cutoff.

[6] Notice that as long as tests are of the suggested cutoff structure, we can construct exactly the same equilibrium as in Proposition 1, but where each certifier sets an arbitrary number of cutoffs, when the fixed cost F is incurred for each cutoff.

[7] With noise, we conjecture that there exists an equilibrium with flexible prices where the second, third and fourth property of Proposition 1 hold. Hence the predictions that we later test for the MBA market should also hold under flexible prices.

Notice also that if the entering certifiers choose the same cutoff, flexible prices will mean Bertrand competition and negative profits. Hence there cannot exist such a symmetric equilibrium.

on pricing behavior. The pricing behavior of Proposition 1 could in a repeated setting be sustained as a subgame-perfect equilibrium (for a sufficiently high discount factor) by other certifiers punishing a deviating certifier by dumping the price of certification.[8]

While the constructed equilibrium is not unique, in Appendix B we show that it survives a natural refinement, which eliminates many other equilibria. The refinement is constructed by perturbing the game slightly, by including a small positive probability of potential entrants not using their entry possibility even when the existing certifiers make a positive profit.[9] In Section 3.3, we consider the case when the certification tests are noisy. We show that the constructed equilibrium is robust to the introduction of noise, and moreover that noise ensures that all sellers *strictly* prefers to attend the certifier suggested by Proposition 1.

3.2 Related results

Lizzeri (1999) considers a setting with a monopoly certifier with access to a perfect and zero cost test technology. The main result is that such a certifier will reveal as little information as possible about the sellers that are certified, and subtract all the surplus from the market (this is equivalent to setting a cutoff equal to zero and a price equal to $\frac{1}{2}$). We get the same result for $F = \frac{1}{2}$, where Proposition 1 implies that one certifier enters, sets cutoff equal to 0, and a price equal to $\frac{1}{2}$. For $F \in (\frac{1}{4}, \frac{1}{2})$, there would also be only one certifier entering, but (conditional on this certifier setting the cutoff at zero, which can be sustained as an equilibrium) the price of certification would have to be lower than the monopoly price, to avoid entry. For $F < \frac{1}{4}$, Proposition 1 implies that there will be two or more certifiers entering the market, setting different cutoffs and charging different prices, and the equilibrium will be of a different type than that studied by Lizzeri (1999).

[8]For a recent paper on price collusion in dynamic settings, see Athey et al. (2000). We can notice that the price-setting mechanism in the model is similar to that in the theory of contestable markets of Baumol et al. (1982), since existing certifiers cannot adjust prices in response to entry. However, in contrast to the present theory, the theory of contestable markets lacks a plausible interpretation in terms of dynamic collusion since the contestable market outcome (monopolist pricing equals average cost) does not maximize the joint profits of the incumbent and the (potential) entrant.

[9]This may be due to e.g., government regulation banning the entry of additional certifiers.

Hence we get the same result as Lizzeri (1999), but only in the special case $F = \frac{1}{4}$.[10]

In the product differentiation model of Salop (1979), producers compete for customers on a unit circle. Customers demand one unit inelastically, and trade off transportation costs with price when deciding which producer to attend to. Producers incur a fixed cost each when entering, and in equilibrium all producers make zero profits.

Both the Salop (1979) model and the present model have the property that the free entry condition drives profits to zero, and that the number of active firms is determined by the size of the fixed cost. When the fixed costs go to zero in the Salop model, the market converges to a competitive market (prices equal marginal cost, which we can think of as zero). It is interesting to notice that pricing in the limit case is very different in our setting.

Remark 1 *As F tends to zero,*

- *The price charged for certifying a product with quality x, equals x, i.e., perfect price discrimination.*

Furthermore,

- *Certifiers become distributed according to the frequency function $2x$.*
- *There is full revelation of private information.*

Proof. We first prove the first and the third part of the result, and then the second part. In the equilibrium outlined in Proposition 1, certifier k attracts all sellers on the interval $[I_k, I_{k+1})$, and charges the price $P_k = \dfrac{(I_k + I_{k+1})}{2}$, where $k = 1, ..., n$. I_k, I_{k+1} and n are determined such that all certifiers make zero profits, and in particular certifier k makes zero profits. By making F small, zero profits of certifier k implies that $|I_{k+1} - I_k|$ can be made arbitrarily small, and hence that P_k tends to I_k when F tends to zero. It also follows that as F tends to zero, the number of certifiers grow (and choose different cutoffs)

[10] The second main result of Lizzeri, Theorem 6, says that if there are two or more certifiers in the market, who both have access to a perfect test technology, there will be full revelation of private information, by a Bertrand competition type of argument. In contrast, full revelation will only be an equilibrium in our model when the fixed cost of testing approaches zero (see Remark 1).

and we can get arbitrarily close to the case where all private information is revealed. Now the second part. Let $H(x;F)$ be the fraction of certifiers that set a cutoff below x in equilibrium. We derive this function and show that it equals x^2 when F tends to zero. From Proposition 1, it will be the k-th certifier from above that will have cutoff equal to x, where k is given by the solution to,

$$\sqrt{1-2kF} = x. \tag{4}$$

Using this expression gives $H(x) = x^2$ and $h(x) = 2x$, where $h(.)$ is the frequency function. ∎

3.3 Noisy tests

In this section we add noise to the basic model. The purpose of the section is twofold. First, we show that the equilibrium derived in the previous section is robust to the introduction of noise, and that noise ensures that all sellers strictly prefers to attend the certifier it attends according to Proposition 1, given the behavior of certifiers. Second, we show that with noise, the net gain from being certified must be increasing in x in equilibrium, an implication we later on will attempt to test.

Assume now that the certification technology is not flawless, so that certifier k observes the quality of a seller with a normally distributed noise ε_{σ_k}, with mean zero and standard deviation σ_k. As before, we will be looking for an equilibrium with cutoffs $0 < I_1 < \cdots < I_n < 1$, where the sellers on $[I_k,\ I_{k+1})$ attend to certifier k, and the sellers in $[0,\ I_1]$ are not certified. We will now have another host of free parameters Π_k – the probability with which type I_k fails the test of certifier k.

I_k and Π_k determine the quality type t_k that passes the test of certifier k with probability half. This type t_k is the 'announced' cutoff of certifier k, and it can be found by using the inverse of the cumulative normal distribution with variance σ_k^2. However, t_k will play no explicit role in the analysis.[11]

Let $E_k(\sigma_k, I_k, \Pi_k, I_{k+1})$ be the expected payoff of type I_k when she goes to certifier k.

[11] A seller passes (fails) the test of certifier k if $\tilde{x} > t_k$ ($\tilde{x} < t_k$), where $\tilde{x} = x + \varepsilon_{\sigma_k}$. Notice that $I_k = t_k$ in the deterministic version of the model, but that will no longer be true with noise.

If $S_k(\sigma_k, I_k, \Pi_k, I_{k+1})$ is the average successful type in the interval of types $[I_k,\ I_{k+1})$ that take test k, and $F_k(\sigma_k, I_k, \pi_k, I_{k+1})$ is the average failing type in $[I_k,\ I_{k+1})$, then

$$E_k = (1 - \Pi_k)S_k + \Pi_k F_k. \tag{5}$$

When σ_k and π_k are very small, then S_k is close to $\frac{1}{2}(I_k + I_{k+1})$, because the ratio of success probabilities (densities, to be precise) of types in different parts of $[I_k,\ I_{k+1})$ is almost 1:1. Therefore, E_k tends to $\frac{1}{2}(I_k + I_{k+1})$ when σ_k and Π_k tend to zero.

Denote by $\pi_k(\sigma_{k-1}, I_{k-1}, \pi_{k-1}, I_k)$ the probability that I_k would fail the test of certifier $k-1$. Clearly, $\pi_k < \Pi_k$. Thus

$$H_k(\sigma_{k-1}, I_{k-1}, \pi_{k-1}, I_k) = (1 - \pi_k)S_{k-1} + \pi_k F_{k-1} \tag{6}$$

would be the expected remuneration of type I_k had she gone to certifier $k-1$. By the same argument as before, H_k tends to $\frac{1}{2}(I_{k-1} + I_k)$ when σ_{k-1} and π_{k-1} tend to zero.

There are two sets of equilibrium conditions. Condition (i_k) expresses the *indifference* of type I_k between taking the test of certifier k or certifier $k-1$:

$$E_k(\sigma_k, I_k, \pi_k, I_{k+1}) - P_k = H_k(\sigma_{k-1}, I_{k-1}, \pi_{k-1}, I_k) - P_{k-1} \tag{i_k}$$

Condition (p_k) expresses the *zero profit* of certifier k:

$$P_k(I_{k+1} - I_k) = F \tag{p_k}$$

Now, when Π_k and σ_k are zero (so that ε_{σ_k} is the unit mass at zero), then $E_k = \frac{1}{2}(I_k + I_{k+1})$ and $H_k = \frac{1}{2}(I_{k-1} + I_k)$, and the system becomes

$$\frac{1}{2}(I_k + I_{k+1}) - P_k = \frac{1}{2}(I_{k-1} + I_k) - P_{k-1} \tag{i_k^0}$$

$$P_k(I_{k+1} - I_k) = F \tag{p_k^0}$$

The equilibrium I_k, P_k from the previous section is clearly a solution to this system of equations. The question is, therefore, whether for small enough Π'_k and σ'_k we can find close-by solutions I'_k, P'_k that solve the perturbed system i_k, $p_{k.}$

The answer to this question is positive, as the following proposition shows.

Proposition 2 *The equilibrium of Proposition 1 is robust to the introduction of a small degree of noise. Moreover, for any degree of noise, there exists an equilibrium with the same structure as in Proposition 1, except for the behavior of the bottom certifier.*

Proof. See Appendix A. ■

The equilibrium with noise is the same as the equilibrium without noise with respect to the distribution of cutoffs and prices, except for the behavior of the bottom certifier. In the noisy equilibrium some sellers fail the test (which can be interpreted as not being certified). As can easily be shown, the market value of those objects passing the test of certifier k must be higher than those objects failing to pass the test of certifier $k + 1$.

On the net gains from certification, the deterministic model tells us that the returns are constant in x. As an instant corollary of the Proposition 2, we get the following result on the distribution of net surplus under noise.

Corollary 1 *With noise, the (expected) net surplus from certification is strictly increasing in x.*

The intuition for the result is that with noise, a seller with a higher x has a higher probability of passing a given test, and hence must obtain a higher net surplus in equilibrium than a seller with a lower x.

Notice that this type of result would follow in any model of certification (with noise) where a high type can imitate the behavior of a low type and get at least as high payoff, which seems almost a defining feature of certification (for example, we can think of much more general test structures, accommodating richer estimates of the object's value, and a more general cost function underlying the certification process).

This type of monotonicity result is standard in signaling models, where a higher type can imitate the behavior of a lower type and obtain at least the same payoff (see e.g., Fudenberg & Tirole, 1992). The main difference between the present model of certification and models of signaling, as in Spence (1973), is that while signaling models treat the institution that directly or indirectly transmits information to the market as passive entities, we treat them as active, strategic, players.[12] Hence we can view the present model of certification as a step towards providing a microfoundation for signaling models, since we get a similar type of equilibrium, but resting on more primitive assumptions about market structure. In particular, in our setting prices (tuition fees) and signal informativeness depend on the structure of equilibrium rather than being assumption-based.[13]

4 Empirics

We have constructed a model of certification with multiple certifiers, where different certifiers attract different segments of the market and charge different prices. In this section, we wish to confront the theory with data.

Suppose that we rank certifiers according to how much they (on average) add to the market value of the objects that are certified. Then the two main empirical implications of the model are that: (1) Certifiers with higher rank charge higher prices for certification, and that (2) Net surplus of a seller is increasing in the rank of the certifier the seller attends to, holding pre-certification market information about its value constant.

We choose the market for MBA education as a testbed for the theory for two reasons. The first is that certification presumably plays an important role in this market, and the second reason is that relevant data, e.g., on pre-MBA and post-MBA wages, and the costs of tuition, is relatively easily accessible.

Before we proceed with the analysis, we can notice that within finance, there is a large empirical literature on the certifying role of various financial institutions, starting with the proposal of the 'Certification Hypothesis' by Booth & Smith (1986). For example, Megginson & Weiss (1991) tests whether venture capitalists fill a certifier role when backing IPOs, and Puri (1996) investigates the certifying role of investment banks and

[12]For example, Weiss (1983) considers a setting where employers offer contracts that condition payment on a final test. In the final test of Weiss (1983), there are two grade levels, 'fail' and 'pass', as in our setting. However, in contrast with our setting, the test is the same for everyone, and neither the test standard nor the tuition fees are subject to choice by the education institution.

[13]The usual interpretation of costs in the Spence model is that of cost of effort, but clearly cost of tuition must enter the picture too.

commercial banks (before the Glass-Steagall Act). The present paper is to our knowledge the first paper to include an empirical analysis of certification that i) is based on an equilibrium model, and ii) takes into account both the market value increase and the cost of being certified (the papers cited above consider only the market value increase). Let us now describe the data, discuss our test strategy, and then describe the empirical results.

4.1 Data

Our primary source of data is the Financial Times 2001 ranking of MBA programs worldwide based on the 1998 class (FT 2001). FT 2001 includes information on (average) student characteristics at each program, such as salaries before and 3 years after the MBA, percentage of international students, alumni networks, etc. FT 2001 also includes data on program characteristics such as faculty research output, and faculty Ph.D. ratio, sex ratio, etc. In addition to the FT ranking we use the *Official MBA Guide* for information on GMAT scores and costs of tuition for the programs. We confine the analysis to the two-year US programs in the FT 2001 that provides tuition fees and (average) GMAT scores in the Official MBA guide, which gives a sample size of 48 programs.[14]

4.2 Test strategy

If MBA students were observationally equivalent in the market ex-ante, their wages would be the same before the MBA, and we could rank programs according to the post-MBA wages they generate. In that case, we could test hypothesis (1) simply by evaluating the correlation between post-MBA wages and the costs of tuition. However, different programs attract students with different *observable* characteristics (in contrast to in the model), and therefore post-MBA wages is not a proper measure of program rank. To control for student heterogeneity when testing hypothesis (1), we therefore regress post-MBA wage on the cost of tuition, controlling for pre-MBA wage and GMAT differences, and interpret the resulting coefficient as the relation between program rank and cost of

[14] 100 programs are ranked in FT 2001. All wage figures are indexed to the 2000 level. Since the cost of tuition is relatively stable over time, we have used the easily available cost of tuition for year 2000 figures, rather than indexing the 1995 figures.

tuition.[15] A positive and significant coefficient would then indicate that a higher post-MBA value is associated with a higher cost of tuition, and would confirm (1).

To test hypothesis (2), we need to take into account that an MBA degree is an investment it can take several years to justify. We therefore construct a measure of net value added (NVA) that takes into account both the stream of income generated from an MBA degree, the stream of foregone income, and tuition costs. We then regress NVA on a measure of the rank of a program, controlling for differences in student quality that are observable in the market ex-ante. If the coefficient on the rank of program is positive, we take this as evidence in favor of hypothesis (2). Since pre-MBA wage is included in our measure of NVA (to evaluate opportunity costs), we can only control for (observable) ability characteristics with the GMAT variable. Also, since it is problematic to construct a rank of a program that is not based on variables that are already included in NVA, we use the research rating index provided by Financial Times as a proxy for rank.[16]

Before describing the tests in more detail, let us offer two comments. First, strictly speaking we should decompose the effect of attending an MBA program into two parts, the value added stemming from increases in human capital, and the value added that stems from certification, i.e., the identification of student qualities that are not observable in the market ex-ante. Given the data limitations, we cannot perform such a decomposition, and we will for now simply assume that the increases in value due to human capital acquisition is roughly constant across programs, in which case human capital acquisition will only turn up in the regression intercepts.[17]

Second, while there are no entry rejections in the model (and sellers 'apply' to one certifier only), entry rejections clearly take place in the real MBA market, reflecting noise

[15] Although GMAT scores are probably less observable than wages in the market ex-ante, including this variable is a simple way of correcting bias due to omitted observable variables such as occupational level (affecting e.g., expected career path) and geographical variations in employment (affecting take home value of salary).

[16] The research rating of a program is a number on a scale from 0 to 100 based on publication in scientific journals of the faculty of that business school. For example, Harvard gets 100, Wharton 91, Stanford 85, MIT 70, Northwestern 53, Yale 40, Wisconsin 28, and Thunderbird 17.

[17] A third possible gain from undertaking an MBA degree is that of establishing contacts in the business world, that can turn important later in the career. Such networking is a good example of the certification that goes in within programs (and can be reflected in the costs of tuition): the signal received after certification (in the noisy version of the model) can be interpreted as being accepted into an important student group or not, rather than as grades.

in the admittance process. Although entry decisions are noisy (at least from the student's standpoint), it is probably true that entry decisions are rather deterministic within a class of programs. For example, a good student applies for all programs between rank 5 and 10, and is admitted to at least one of them with a high probability. As long as the strength of the certification is not significantly different between the program ranked 5 and the program ranked 10, this difference between the model and reality is not essential.

4.3 Results

We first evaluate hypothesis (1), by regressing post-MBA wage on the cost of tuition, pre-MBA wage and GMAT scores. We obtained the following results (standard deviations in parentheses).[18]

Table 1 Relation between post-MBA wage and tuition cost

	MBA 2001		MBA 2000	
Variable	(I)	(II)	(III)	(IV)
Intercept	1079581	48964	-76227	55284
	(1235704)	(12659)	(1354858)	(14036)
Salary before	0,593	...	0,489	...
	(0,388)		(0,361)	
GMAT	-3623	...	-115	...
	(3762)		(4116)	
GMAT^2	310	...	0,47	...
	(287)		(3,137)	
Tuition cost	0,809	1,44	0,667	1,29
	(0,273)	(0,303)	(0,278)	(0,329)
n	48	48	41	41
R^2	64%	33%	62%	28%

Considering first (II), we find a strong positive raw correlation between post-MBA wage and tuition cost (TC). Since a higher cost of tuition may reflect both improved

[18] The regressions were performed in MINITAB. The regression procedures are obtainable from the authors.

unobservable *and* observable student characteristics ex-ante, in column (I) we control for observable differences in student quality by including pre-MBA wage and GMAT scores in the regression. The relation between post-MBA wage and TC is now weaker, as expected, but it is still positive and highly significant.[19] To check the robustness of this finding, we performed the same regressions on the FT 2000 data and obtained very similar results, see (III) and (IV).[20] Hence the support of (1) seems fairly strong in the data.[21]

We now evaluate hypothesis (2). We confine the analysis to constructing a measure of NVA from the start of a program to four years after graduation, expecting the returns in this 6-year window to be highly correlated with the total returns. Undertaking an MBA degree has three effects on the stream of income during the 6-year interval. The negative effects are the payment of tuition fees and two years of foregone income, and the positive effect is the salary jump resulting from a degree. We assume that the rate of salary growth, x, is the same with and without a degree.[22] Denote the pre-MBA wage by w_{t-2} and the wage three years after graduation as w_{t+3} and define NVA as,

(Net value added) $$NVA := a(x)w_{t+3} - b(x)w_{t-2} - TC$$

The first term on the right side reflects the stream of income after an MBA is undertaken. The second term reflects the opportunity cost of undertaking an MBA, and the third term is the cost of tuition. Setting x to 0% gives $a = 4$ and $b = 6$, while setting x to e.g., .5% gives $a = 3,91$ and $b = 6,80$.[23]

[19] For FT 2001, the t-value for the coefficient on tuition cost is 2,97, and the corresponding p-value equals 0,005.

[20] However, the similar findings can partly be explained by the same cost and GMAT data being used for the two years, and we therefore performed an alternative test of (1). In this alternative test, we first generated a rank of schools, according to the procedure of Tracy & Waldfogel (1997). This procedure regresses post-MBA wage on student characteristics, and ranks schools according to the magnitude of the residuals from this regression. To test (1), we then regressed the residuals on TC, and obtained the same type of results here as those expressed in Table 1.

As a curiosity, the induced ranking for the FT 2001 became: 1. Columbia, 2. Wharton, 3. Chicago, 4. Harvard, 5. Cornell, 6. Emory, 7. Georgetown, 8. Duke, 9. Vanderbilt, and 10. Southern Methodist.

[21] We can notice that the result is also consistent with a full-information human capital explanation, where a higher increase in human capital implies a higher cost of tuition. The data limitations prohibit us from exploring the relative merit of the certification explanation and the human capital explanation.

[22] With data only on wages at two different points in time, it is not possible to identify both growth rates and the wage jump resulting from an MBA degree.

[23] For a given x, the coefficients a and b are determined as, $a(x) = \sum_{j=0}^{2} \frac{1}{(1+x)^j} + (1+x)$, and $b(x) =$

We wish to test whether NVA is positively correlated with rank, holding student characteristics constant. Again, because of the identification problems associated with using post-MBA wage as a measure of rank and w_{t-2} as a measure of the (observable) individual effect, we use the research rating index provided by the Financial Times as a proxy for the certification effect, and GMAT scores to control for observable student characteristics.[24] For regressions (V) and (VI), we use $x = 8\%$, which gives $a = 3,86$ and $b = 7,33$.

Table 2	Determinants of NVA	
	MBA 2001	MBA 2000
Variable	(V)	(VI)
Intercept	2767032	-4296144
	(5088130)	(5698778)
Research rating	952	875
	(578)	(533)
GMAT	-9742	11447
	(15509)	(17353)
GMAT^2	8,1	-7,8
	(11,81)	(13,19)
R^2	27%	35%

The interpretation of the coefficient on the research rating variable is the effect on net value of being admitted to a higher program, holding (observable) student quality constant. The estimated increase in NVA from being admitted to a program with one point better research rating is approximately $900 in both samples.[25] This result is robust to the specification of the growth rate. For $x = 5\%$, the coefficient on research rating is 1108 (566), and for $x = 10\%$, the coefficient is 847 (588). We also got similar results

$\sum_{j=0}^{5}(1+x)^j$.

[24] In the 2001 sample, the correlation coefficient between research rating and the ranking obtained by using the Tracy-Waldfogel procedure equals 0.4, and the correlation between $GMAT$ and w_{t-2} equals to 0.49. Data limitations prohibit us from using instruments that are more highly correlated with the independent variables.

[25] The p-values are approximately .10 for both samples. However, since GMAT scores do not capture all observable individual characteristics, we expect the $900 estimate to be biased somewhat upwards, since increased research rating also will reflect observable differences in increased student quality.

from letting the growth rate with an MBA be higher than the growth rate without an MBA. Extending the window to four years after graduation gives a higher estimated coefficient on research rating (1417), and a lower p-value (0,059). In sum, these findings give support to (2); that NVA is positively correlated with being admitted to a program of higher rank.[26]

5 Welfare and Public Policy

In this section we make some remarks on the effect of intermediaries on welfare. Let us define social surplus as total seller surplus + total profits for certifiers, and for simplicity consider an environment where projects are distributed uniformly on $[a, b]$, where $a < b$ and $b > 0$. Notice that trade efficiency implies that only the objects on $[0,b]$ are traded. For simplicity, we consider the deterministic version of the model, with $\frac{1}{2F} \in \{1, 2, 3, ...\}$.

Remark 2 *In the equilibrium constructed in Proposition 1, the social surplus generated is 0, and hence the existence of certifiers does not increase social surplus.*

Proof. First consider the case when $a \geq 0$. In that case, we can without loss of generality normalize, and set $a = 0$ and $b = 1$. Notice that with no intermediary in the market, the social surplus generated is equal to $\int_0^1 dx = \frac{1}{2}$. With certifiers, we need to subtract the cost of testing. Recall that the number of active certifiers equals $\frac{1}{2F}$, the cost per certifier equals F, and hence there is full dissipation of rents for any $F > 0$, since $\frac{F}{2F} = \frac{1}{2}$. Now consider the case $a < 0$. There are then two cases, $E(x) < 0$ and $E(x) > 0$. In the first case, there will be no trade without certifiers, and social surplus equals zero, as is the case with entry of certifiers. In the latter case, there will be positive social surplus

[26] Two remarks. First, we noticed in the theoretical part that (2) would follow from any model of certification where a high type can imitate the behavior of a low type and get at least as high payoff, which seems to be almost a defining feature of certification. Hence the test of (2) can perhaps primarily be viewed as a test of whether a broad class of certification models make sense for the MBA market, rather than only the particular model constructed.

Second, under the competing human capital acquisition interpretation of MBA education, (2) is not obviously true because which school fits best to a student can be a matching question. For example, a mediocre student might not be 'up to it' at e.g., Harvard. The confirmation of (2), and also the larger rejection rates at higher ranked places, indicate that either matching is not important (contrary to standard MBA wisdom) or that certification is important.

without certifiers and zero social surplus with certifiers. Hence, the existence of certifiers cannot enhance welfare. ∎

Hence, a market with free entry of certifiers is characterized by low welfare, due to the cost of testing offsetting the potentially improved gains from trade.[27] The intuition is that in the equilibrium constructed in Proposition 1, certifiers make zero profits, and moreover each certifier exercises monopoly power over its segment of the market, so that seller surplus is also low.

Notice that with noise and with $\frac{1}{2F} \notin \{1, 2, 3, ...\}$, the negative result will modified, since there will be some social surplus, but not by much.[28] We can also notice that there is nothing tautological in free entry and fixed costs implying a low welfare level, as can be seen from the Salop (1979) model, where competition can drive prices down to marginal costs, for sufficiently low fixed costs.[29]

In the extension of this negative result, it is natural to discuss the role of public policy. Leland (1977) argued that minimum quality standards can enhance trade surplus, by shutting off the lemons from the market. While the minimum quality standards in Leland (1977) are enforced directly by the regulators, in our setting it is natural to think of minimum quality standards as being enforced by certifiers, and the policy makers regulating trade through regulating the certifiers.

Assuming that F is sufficiently low, trade efficiency implies that only objects with value above 0 are certified. The following remark shows that trade efficiency can be obtained by simply allowing only one certifier (perhaps a governmental agency, as is common for e.g., driving licenses).

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[27] The analysis of the MBA market gives some empirical support to this result, in that the mean net value added four years after graduation lies between -50.000$ and -100.000$ (depending on discounting factor).

[28] This follows from the fact that with $\frac{1}{2F} \notin \{1, 2, ...\}$, the sum of seller surplus must equal the mass below the first certifier, which will be small for F small, see Appendix A. Of course, we can construct examples where $\frac{1}{2F} \notin \{1, 2, ...\}$ and $E(x) < 0$, where the existence of certifiers enhances welfare. But comparing it to the magnitude of welfare loss in the cases where $E(x) > 0$, the basic message of Proposition 2 is valid.

We can also notice that in a (non-collusive) equilibrium with price competition, the negative result will also be modified, since certifiers lower prices from the monopoly level to attract sellers, as in the Salop (1979) model of product differentiation.

[29] Since consumers demand one unit inelastically in the Salop model, consumer surplus would be infinite for any finite price. To make a proper analysis of welfare, we would thus strictly speaking need to adjust the Salop model by assuming a finite reservation price.

Remark 3 *Allowing only one certifier ensures trade efficiency, but this monopolist takes all surplus in the market.*

Proof. As can easily be shown, there exists an equilibrium where the monopolist certifier sets the cutoff at zero and a price such that all the seller surplus is extracted. By setting the cutoff different from zero, the trade surplus will be less, and the profit must in that case also be less. ■

With this solution, all surplus in the market is accrued by the certifier. Notice that the same type of results exists when tests are noisy. The key to understanding this result is that the certifier can set I very low (or very high), to mimic the solution of the deterministic case.

It may be tempting to obtain a less skewed distribution of surplus in the market by regulating the price set by the certifier. However, such a policy is implemented at a cost, as the following result points out.

Remark 4 *Under price regulation, too many objects will be certified and traded.*

Proof. For a given price set by the policy makers, $P^G < \frac{1}{2}$, the monopolist sets I as low as possible, subject to the constraint that the sellers prefer being certified to not being certified. Assuming that not being certified has value zero (which will be confirmed in equilibrium), we must have that,

$$P^G \leq (1+I)/2, \text{ or equivalently,} \tag{7}$$

$$I \geq 2P^G - 1 \tag{8}$$

Since the monopolist maximizes profits, this inequality must be binding, and hence $I = 2P^G - 1$. It follows that if $P^G < \frac{1}{2}$, then $I < 0$, and too many objects are traded. ■

While the distributional problem outlined in Remark 3 can be alleviated by proper profit taxes (rather than through price regulation), a perhaps more serious problem of the monopoly solution is that, since sellers make a low surplus, there are be low incentives for investments in quality upfront. To admit only one certifier in the market can hence induce a more efficient level of trade, but a low level of investments.[30]

The optimal regulation given concerns about both trade efficiency and investment levels is a challenging question, one reason being that one needs to specify both the instruments and the information available to the policy makers. We leave this question for future study, but remark that in the case where the policy makers can affect only I, it may be optimal to set I in a manner that conflicts with trade efficiency, because a high I may ensure a high level of investments, but may also shut off from the market objects that should have been traded.[31]

6 Conclusion

We have constructed a model of certification with fixed costs and free entry, where each certifier differentiates its certification test according to which segment of the market it targets. The model accommodates several stylized facts from certifying markets such as there being several active certifiers, where different certifiers capture different segments of the market, and where the increase in market value from being certified is highly dependent on which certifier issued the certificate.

From the model, we derived the testable implications that the price for being certified should increase in the rank of a certifier, and that the net surplus of sellers should increase in their object's true value. We investigated the validity of these two predictions in the market for MBA education and received empirical support for both.

We also used the model to consider questions of regulation and minimum quality standards, when the regulators cannot observe quality directly, and showed that allowing only one certifier into the market can ensure trade efficiency, but that incentives for investments can be low under such a policy.

One extension of the present work would be to apply the model to other settings than

[30]In the same type of settting as Lizzeri (1999), Albano & Lizzeri (2001) considers the incentives for a monopolist certifier to reveal information about the projects being certified, when the monopolist takes into account that no revelation (as in Remark 2) gives no incentives to invest in quality.

[31]A related issue is whether the policy makers would want to allow the monopolist to certify several standards, or by allowing more than one certifier to enter, in order to increase the incentives for making investments in quality.

the MBA market. For example, it would be interesting see whether the predictions of the model finds support in the market for investment bank certification of IPOs, or in the venture capital market. Another extension would be to discuss policy questions in more detail, taking into account informational and institutional restrictions of real markets.

7 Appendix A: Proofs

In this appendix we first show that there exists an equilibrium 'close' to the equilibrium proposed in Proposition 1 when $\frac{1}{2F} \notin \{1, 2, ...\}$, and then prove Proposition 2.

7.1 Proof of Proposition 1

We look for an equilibrium with cutoffs $0 < I_1 < \cdots < I_n < 1$, where all sellers are indifferent between being certified and not being certified, and where their remuneration will be $s = \frac{I_1}{2}$.

The individuals in $[I_n, 1]$ will therefore be willing to pay at most

(A1)
$$P_n = \frac{I_n + 1}{2} - s.$$

The zero-profit condition for certifier n is hence

(A2)
$$F = P_n(1 - I_n) = \left(\frac{I_n + 1}{2} - s \right) (1 - I_n).$$

The quadratic equation for I_n is thus

(A3)
$$(I_n)^2 - 2sI_n - (1 - 2s) + 2F = 0$$

with the relevant root

(A4)
$$I_n = s + \sqrt{s^2 + 1 - 2s - 2F}.$$

We therefore have

$$P_n = \frac{I_n + 1}{2} - s = \frac{\sqrt{s^2 + 1 - 2s - 2F} + 1 - s}{2} \tag{A5}$$

Similarly, the individuals in $[I_{n-1}, I_n]$ will be willing to pay at most

$$P_{n-1} = \frac{I_{n-1} + I_n}{2} - s, \tag{A6}$$

and the zero-profit condition for certifier $n - 1$ is

$$F = P_{n-1}(I_n - I_{n-1}) = \left(\frac{I_{n-1} + I_n}{2} - s \right) (1 - I_n). \tag{A7}$$

The quadratic equation for I_{n-1} is thus

$$\begin{aligned} 0 &= (I_{n-1})^2 - 2sI_{n-1} - I_n(I_n - 2s) + 2F = \\ &\quad (I_{n-1})^2 - 2sI_{n-1} - (1 - 2s - 2F) + 2F \end{aligned} \tag{A8}$$

with the relevant root

$$I_{n-1} = s + \sqrt{s^2 + 1 - 2s - 4F}. \tag{A9}$$

We thus have

$$P_{n-1} = \frac{I_{n-1} + I_n}{2} - s = \frac{\sqrt{s^2 + 1 - 2s - 4F} + \sqrt{s^2 + 1 - 2s - 2F}}{2} \tag{A10}$$

Inductively, when we finally get to I_1 we get the solution

$$2s = I_1 = s + \sqrt{s^2 + 1 - 2s - 2nF}. \tag{A11}$$

Hence

$$s = \frac{1 - 2nF}{2} \tag{A12}$$

so the maximal n for which there is a solution is

(A13) $$n = \left\lfloor \frac{1}{2F} \right\rfloor,$$

and

(A14) $$I_1 = 1 - 2nF.$$

We can now substitute s in all the above equations, and express the $I_k - s$ and $P_k - s$ as a function of F and n (the expressions are not illuminating, though).

Taking the largest possible n for a given F, one can see that the smaller F is, the smaller is also the difference between $n = \left\lfloor \frac{1}{2F} \right\rfloor$ and $\frac{1}{2F}$, and therefore the smaller is also $s = \frac{1-2\left\lfloor \frac{1}{2F} \right\rfloor F}{2}$. Hence, although there will be a surplus for the worker when $\frac{1}{2F} \notin \{1, 2, ...\}$, the surplus will be small when F is small.

7.2 Proof of Proposition 2

There exists such a perturbed solution where I_1' is smaller than I_1 but arbitrarily close to it, while $I_k' = I_k$ for $k = 2, \ldots, n$ (and therefore, by condition (p_k), $P_k' = P_k$ for $k = 2, \ldots, n$). To see this, suppose that $I_1' = I_1 - \varepsilon$, for an arbitrarily small but positive ε. Then in comparison with the benchmark equilibrium, the payoff from not getting certified decreases by $\frac{\varepsilon}{2}$. If certification were faultproof, the gross payoff from going to the first certifier (net of the certification cost) would also decrease by $\frac{\varepsilon}{2}$. However since now $I_2' - I_1' = I_2 - I_1' > I_2 - I_1$, by condition (p_1) we have that $P_1' < P_1$. Thus, to make the type I_1' just indifferent between going to the first certifier and not getting certified at all, all that is needed is to design Π_1' (the probability that type I_1 passes the first certifier) so that the decrease in its price is compensated by the further decrease in the expected payoff:

(A15) $$P_1 - P_1' = \frac{I_1' + I_2'}{2} - E_1'$$

Once Π'_1 is determined, so is π'_2 – the probability of the type $I'_2(= I_2)$ to pass certifier 1, and therefore also H'_2. Inductively, suppose H'_k has been determined. One has now to choose Π'_k (which, given $I'_k = I_k$ and $I'_{k+1} = I_{k+1}$, determines also E_k) so that condition (i_k) holds. Repeating this procedure consecutively for $k = 2, \ldots, n$ establishes the perturbed equilibrium.

That all sellers strictly prefer to attend to the certifier suggested (except those with $x = I_k$, who are indifferent between attending certifier k and certifier $k-1$) follows from the following argument. If type I_k went to certifier $k-1$, it would be further to the right from the mean t_{k-1} than the extent it would be to the right of the mean t_k when it goes to certifier k. Now notice that the cumulative probability function flattens towards the far right (this is a general property of distributions with a finite mean and infinite support - not just a property of the normal distribution.) So type $x > I_k$ has only a slightly bigger probability than I_k to pass the test of certifier $k-1$, and a relatively bigger advantage over I_k in the chances to pass certifier k. So if I_k is indifferent between certifiers k and $k-1$, any type $x > I_k$ strictly prefers certifier k over certifier $k-1$. This argument establishes that any $x \in (I_k, I_{k+1})$ prefers to attend certifier k to attend certifier $k-1$. The same type of argument can be used to prove that type $x \in (I_k, I_{k+1})$ prefers certifier k to certifier $k+1$, and by induction that type $x \in (I_k, I_{k+1})$ prefers certifier k to all other certifiers.

8 Appendix B: Uniqueness

The equilibrium constructed in Proposition 1 rests on two sets of off-the-equilibrium-path beliefs. First, sellers believe that if they are not certified, buyers take this as an indication of their object being the worst possible quality. Since all sellers are certified in equilibrium, these beliefs are not contradicted in equilibrium. Second, a certifier believes that if he has positive profits if there would be no more entry, then there will be other certifiers entering and ruining his profits. Since certifiers make zero profits in equilibrium, neither of these beliefs are contradicted in equilibrium. These off-equilibrium-path beliefs are consistent with many other equilibria too, since essentially all that is required from equilibrium is that all active certifiers make zero profits. The purpose of the following discussion is to show that given the out-of-equilibrium-path beliefs, the constructed equilibrium survives a natural refinement, which eliminates many other equilibria. The idea of the refinement is that if there is a positive probability of potential entrants not using their entry possibility, even when the existing certifiers make a positive profit, the first certifier entering at stage 1 will have incentive to enter at the bottom of the interval (I_1), to ensure positive profits in the case where other certifiers are shut off from the market. By the same argument, the next certifier will have incentive to enter not too far from the first certifier (I_2), and so forth, until an equilibrium similar to the one proposed will be played (with probability (1-ε)^n). Here, we confine ourselves to showing how the argument works for $F = \frac{1}{4}$.

For $F = \frac{1}{4}$, the proposed equilibrium has two active certifiers, with cutoffs and prices equal to $I_1 = 0$, $P_1 = .35$, and $I_2 = .71$, $P_2 = .85$. Suppose now that with some exogenous probability ε, where ε is small, the market will be closed for entry after the first certifier has entered and set (I, P). We now consider four different strategies (I, P) for the first certifier entering. i) to play (I_1, P_1) as above, ii) to play (I_2, P_2), iii) to play (I, P), where $I \neq I_1$, such that $\Pi = 0$, and iv) to play (I, P), where $I \neq I_1$,I_2 such that $\Pi > 0$. Π refers to the profit of the first certifier, without entry of any other certifiers.

Now consider the payoff from playing the different strategies. As before, we assume that if the entrant is given the opportunity to enter (which occurs with probability 1-ε), there is entry if and only if $\Pi > 0$. Then, playing i) gives zero profits with probability (1-ε) and positive profit with probability ε. Playing ii) gives negative profits with probability ε, and non-positive profits with probability (1-ε), and playing iii) gives zero profits if there is no entry, and at most zero profits if there is entry, so ii) and iii) are dominated by i). Hence we can restrict attention to showing that i) gives a higher payoff than iv), for ε sufficiently low.

Playing iv) gives a (positive) profit Π_M with probability ε and a (possibly negative) profit Π_D with probability 1-ε. We wish to show that for sufficiently low ε,

$$\varepsilon\Pi > \varepsilon\Pi_M + (1-\varepsilon)\Pi_D \tag{B1}$$

A sufficient condition for the inequality to hold is Π_D negative. Suppose that entry takes place, and that the entrant makes a non-negative profit. Since the proposed equilibrium maximizes joint profits, which equals zero, the first certifier must then make negative profits after entry, and hence Π_D is negative. We have hence shown that the proposed equilibrium survives the refinement. Notice that, under the refinement there does not exist equilibria with less than two certifiers entering. The only other equilibrium that survives the refinement is the symmetric equilibrium with two certifiers entering, which both choose $I = 0$ and $P = \frac{1}{2}$. Which of these two equilibria will be played depends on the beliefs of the first entering certifier about the behavior of the second certifier. For example, the first certifier may believe that setting $I = 0$ and $P = \frac{1}{2}$ induces the second entering certifier to set $I = 0$ and $P = .35$, in which case the proposed equilibrium will be played.

9 References

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