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The Effect of Inaccurate Quality Signaling under Information Asymmetry

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Abstract

Purpose - This study attempts to provide a new theoretical perspective on the quality signaling and its impact on a market under information asymmetry, focusing on how the accuracy and the cost of quality signaling affect sellers' and buyers' profit, suggesting appropriate designs of quality signaling methods which mitigates information asymmetry.

Design/methodology/approach - In order to examine the effect of quality signaling on strategic interactions within the market, we establish an analytic model where market outcomes are determined by seller's quality claim and price, and buyers are risk-neutral. By investigating this analytic model through relevant game trees, we find the subgame perfect Nash equilibria of the market and predict related market outcomes based on sellers' quality signaling strategy.

Findings - Our analytic model shows counterintuitive results that seller profit will be the lowest with inaccurate quality signaling and the highest with no quality signaling, mostly due to the certification cost. Consequently, sellers should proceed with caution if the quality signaling is less than accurate, as it may backfire. We believe that this is due to the fact that the inaccuracy of quality signaling causes some confusion and uncertainty in both sellers and buyers' decision to maximize profit, making it hard for sellers to predict buyers' behavior.

Research implications or Originality - Although the sources and types of quality signaling errors have been investigated in the literature, there has not been satisfactory understanding regarding how inaccuracy of quality certification affects specific market outcomes. We expect that our theoretical model would provide important implications on how to utilize quality signaling to solve adverse selection issues in markets under information asymmetry.

Keywords: Information Asymmetry, Information Disclosure, Lemon Market, Quality Certification
JEL Classifications: D81, D83, M31

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Ⅰ. Introduction

In many marketing contexts, there often exist certain levels of asymmetric information between sellers and buyers such that the seller has more information about the product than the buyer. For example, car dealerships, realtors, stockbrokers and collectibles resellers commonly know the quality (or the condition) of the products being sold, while the buyer does not. The literature on information economics that has originated from Akerlof (1970)'s seminal paper has shown that information asymmetry can cause adverse selection and undermine customers' willingness to pay, eventually leading to a market failure.

The classic theoretical literature has shown that sellers voluntarily engage in quality disclosure if the quality is verifiable by customers (Grossman 1981; Grossman and Hart 1980; Milgrom 1981). According to these studies, sellers provide verifiable quality disclosure in order to differentiate their products from others since rational consumers will infer that the seller's product has the worst possible quality if one does not credibly disclose its quality.[1] These studies have argued that full disclosure is forthcoming and there is no need for mandatory disclosure (Dranove and Jin 2010), as sellers would voluntarily provide verifiable quality disclosure to buyers whenever possible. However, in many marketing settings, the seller's quality disclosure is not readily verifiable. Nelson (1974) has labeled the attributes that customers cannot evaluate before purchase as "experience" attributes while Darby and Karni (1973) have identified attributes that cannot be evaluated even after purchase as "credence" attributes. The collectible memorabilia and used car product markets may be classified as having experience or credence attributes, as most buyers cannot accurately evaluate the quality of those products by themselves before or even after purchase. Therefore, in order to prevent possible market failures when quality disclosure is not readily verifiable, many firms and government institutions use various quality signaling methods such as firm's reputation, warranty, and third-party certifications. Among these signaling methods, third-party certifications are most widely used to mitigate information asymmetry, as it is the most appropriate form of verifiable quality disclosure in a market where customers cannot easily evaluate the product quality.[2] For instance, sellers of collectibles frequently pay grading services to have their products certified, which is quite common with sports trading cards, coins and autographed memorabilia.

The literature on quality certification has thus investigated the effectiveness of certification focusing on whether it solves adverse selection issues or not. For example, Xiao (2010) has shown that the effect of accreditation in the childcare market is not significant, by observing that consumers do not get meaningful information out of accreditation and its contribution on consumer welfare is negligible. The literature has also explained what makes the mechanism work poorly. According to these studies, third-party certifications provide inaccurate information mainly because of the bias or the conflict of interest of certifiers (Edelman 2009; Feinstein 1989; Hong and Kubik 2003; Lim 2001; Michaely and Womack 1999; Prendergast 2007; Waguespack and Sorenson 2011). Moreover, the literature has also listed customer-side issues such as customer confusion (Harbaugh, Maxwell, and Roussillon 2011) and the competitive environment of certifiers (Lizzeri 1999) as primary reasons why certification has errors

1) As this type of verifiable quality disclosure starts from the seller with the highest quality and goes down to sellers with lower quality, Viscusi (1978) has called this an "unraveling process."

2) Regarding experience or credence attributes, warranty may not function well, as customers may not be able to detect product flaws in the first place.

in various situations. Due to these possible failures, certifiers of used cars such as Carfax warn buyers about possible errors or omissions of information at the bottom of every report they provide.[3] Sellers also have to consider related costs when deciding whether to disclose the quality of a product. Although the classic literature on verifiable quality disclosure assumes that the cost of disclosure is either zero or negligible (Grossman 1981; Grossman and Hart 1980; Milgrom 1981), in real market situations, third party certifiers often charge substantial fees for certification. For instance, Becket Grading Services requires a payment of $15 to have a baseball card graded,[4] while PSA's grading service fees range from $7 to $1500 depending on the dollar value of the collectible item submitted for certification. Accordingly, Viscusi (1978) shows that some sellers with lower-quality products would not engage in verifiable quality disclosure as the cost of information disclosure exceeds the benefit, and Verrecchia (1983) finds that the disclosure cost provides noise in interpreting a firm's disclosure effort, which creates an equilibrium threshold level of disclosure.

Therefore, in order to understand how much quality certification helps mitigating information asymmetry of markets, we have to closely examine the inaccuracy of certification. However, although the sources of certification errors have been studied by many studies, there has not been satisfactory understanding about how certification inaccuracy affects market outcomes and the optimal design of the certification that solves adverse selection issues. Therefore, this study attempts to provide a better understanding of the certification mechanism and its impact on information asymmetry in markets through analyzing the effect of certification errors on market outcomes using an analytic model of strategic interactions between buyers and sellers, which is analyzed through relevant game trees. Since there has not been sufficient numbers of studies on specific consequences of inaccurate certification yet, we expect that this paper would provide important implications on how to utilize certification system to solve adverse selection issues in markets under information asymmetry.

Based on this understanding, we develop a theoretical model assuming a market where a monopolistic seller sells a product to a buyer who cannot evaluate the quality of the product. The seller can decide whether to use the quality certification or not, and the buyer decides whether to purchase the product or not depending on the seller's suggested price and the type of information disclosure. We have also assumed that the buyers in this market are all homogenous in terms of their risk sensitivities and are all risk-neutral. In our model, the certification can be inaccurate and can result in an incorrect assessment of the product. Additionally, the seller has to pay a certain fee to use the certification. By observing how the seller and the buyer react to certification and its errors, we analyze how certification accuracy affects market outcomes such as seller profits and buyer surplus. To our surprise, the equilibrium of our model shows that the payoff for sellers will be the lowest with inaccurate certification and the highest without any certification, suggesting that the introduction of incomplete information disclosure to the market is not desirable from the seller's standpoint, and sellers may not benefit from manipulating quality signaling to their advantages. We believe that this is due to the fact that the inaccuracy of certification causes some confusion and uncertainty in both sellers and buyers' decision to maximize profit, making it hard for sellers to predict

3) All Carfax reports contain the following statement: "Carfax depends on its sources for the accuracy and reliability of its information. Therefore, no responsibility is assumed by Carfax or its agents for errors or omissions in this report."
4) http://www.beckett.com/grading/faq

buyers' behavior. Moreover, the certification cost also negatively affects seller profit when sellers use this signaling method. In terms of buyers' payoff, the model basically predicts that buyers' profit is always zero, as a monopolistic seller charges the maximum price the buyers are willing to pay. However, buyer profit might differ in a real market situation where buyers' risk sensitivities vary and buyers' willingness to pay are not perfectly recognizable. Overall, we believe our results provide meaningful implications in establishing optimal information disclosure strategy by showing how the accuracy of certification and its cost affect specific market outcomes.

This paper proceeds as follows. In Section 2, we develop an analytic model assuming a monopolistic market under information asymmetry, where certification can be imprecise and buyers are risk-neutral. In Section 3, we carefully analyze the model and examine the equilibrium profits of sellers and buyers. Based on this analysis, Section 4 makes further predictions on the market outcomes based on the accuracy and the cost of certification. This paper concludes with the discussion of the possible contributions and policy implications in Section 5.

II. The Model Structure

In order to examine the effect of quality signaling, we have established an analytic model that can observe strategic interactions within the market. More specifically, our model consists of buyers and sellers, and information asymmetry among them is assumed such that only sellers know the true quality of the products, and buyers assume the quality depending on the sellers' quality claims and whether the certification is used. We attempt to investigate the effect of certification on various market outcomes in three different conditions: i) when there is no certification, ii) when the accuracy of the certification is 50 percent, and iii) when the accuracy of the certification is 100 percent. We have assumed that when the certification is 50 percent accurate, it shows the true value of the product 50 percent of the times, and random value in the other 50 percent of the times. On the other hand, 100 percent accurate certification always discloses the true value. As is explained above, the price is flexible and sellers can determine the price level that maximizes profit. There is also a certain cost for using the certification, and the buyers in this market are all homogenous in terms of risk sensitivity and are all risk-neutral. The payoff arrangements of sellers and buyers are as follows.

1. Buyer's Payoff

There are two types of buyer's payoff as there is information asymmetry in the market. More specifically, buyer's expected payoff before purchase will not always be the same as the actual payoff from purchase.

1.1. Expected Payoff

Expected payoff for a buyer: $\pi_B = E(v) - p$

The expected payoff for a buyer is decided by both the expected value of the quality (E(V)) and the price of the product suggested by the seller (P). In particular, the expected value of the product (E(V)) can vary according to the characteristics of the available certifications. As buyers are all risk-neutral, there is no additional cost from perceived risk in this analysis. Let's assume that the quality of the product V is uniformly distributed between 0 to V (i.e., U[0, V]).

1.1.1. The Market with 100 Percent Accurate Certification

When the seller shows the certification. As the certification discloses the true quality with 100 percent certification, the certified quality (V_R) is the same as true value (V_T), and it is what buyers expect from the product.

$$\therefore E(V) = V_R = V_T$$

When the seller does NOT show the certification. When the seller does not show the certification, then the buyer assumes that actual quality is the average of certain possible value range, regardless of the level of the seller's claimed value. Let's assume that the range of the buyer's perceived value follows $U[0,X]$, where the maximum value is expected to be X. In this case, the expected value has the following value:

$$E(V) = \frac{X}{2}$$

1.1.2. The Market with 50 Percent Accurate Certification

When the seller shows the certification. The buyer knows that the certification is true 50 percent of the time, and wrong the other 50 percent of the time. If the certification is correct, then the actual quality (V_T) is the same as the certified quality (V_R), which is also the same as the claimed quality (V_C) (i.e., $V_T = V_R = V_C$). If the certification is incorrect, then the buyer assumes that actual quality is the average of entire possible value range ($U[0,V]$), regardless of the level of claimed value.

$$\therefore E(V) = 0.5 \cdot V_T + 0.5 \cdot E(V_T)$$

$$= 0.5 \cdot V_T + 0.5 \cdot 0.5 \cdot V$$

$$= 0.5 \cdot V_T + 0.25 \cdot V$$

When the seller does NOT show the certification. When the seller does not show the certification, then the buyer assumes that actual quality is the average of a certain possible value range, regardless of the level of claimed value. Let's assume that their perceived value has the range of $U[0,X]$, where the maximum value is expected to be X. In this case, a buyer's expected value has the following value:

$$E(V) = \frac{X}{2}$$

1.1.3. The Market without Certification

When there is no certification available and the seller thus cannot show the certification, then the buyer assumes that actual quality is the average of entire possible value range, regardless of the level of claimed value.

$$\therefore E(V) = \frac{V}{2}$$

1.2. Actual Payoff

For buyers, as explained above, expected payoff differs from actual payoff as there is information asymmetry in this market and a buyer cannot accurately evaluate the quality of the product. Therefore, the actual payoff will be decided by true quality (v_T) and the price the uuyer pays.

Actual payoff for buyer: $\pi_B = v_T - p$

On the other hand, if a buyer does not make purchase, then the actual payoff will be zero.

2. Seller's Payoff

The seller's payoff scheme is as follows:

Payoff for seller: $\pi_S = p \cdot n - c_F - c_R$

In the case of the seller, $n\ (E(v), p) = 1, 0$ as a buyer either purchases the product or not depending on the expected value and price. Although c_F is fixed cost for the seller and will always occur, we will assume that c_F is zero for simplicity as this assumption does not change our results. c_R is the cost of using the certification and will be zero if a seller does not use the certification. As we assume that sellers can use flexible pricing and charge the price that maximizes the payoff, a seller will charge $E(v) - \delta$, where δ is a very small value which is negligible and only makes the price slightly lower than $E(v)$ so that buyers decide to make a purchase.

III. Market Equilibrium

Based on this model setup, we can find the subgame perfect Nash equilibria of this model which can predict market outcomes depending on whether there is 100 percent certification, 50 percent certification, or no certification. We will first analyze the case of 100 percent certification, followed by the analysis of 50 percent certification case and no certification case.

1. The Market with Accurate Certification

1.1. Subgame Perfect Nash Equilibrium

When the certification is 100 percent accurate, the subgame perfect Nash equilibrium differs depending on the expected value of the product perceived by customers. In particular, we have to consider strategic considerations of the buyers and sellers as follows.

At first, when the seller does not show the certification, the buyer assumes that actual quality can be any value, and it thus follows $U\,[0,\ V]$. In this case, $E(v) = \frac{V}{2}$ when the seller does not show the certification. Now the expected payoff for a seller when a buyer purchases the product is $v_T - c_R$ when he shows the certification, and $\frac{V}{2}$ when he does not show the certification, as the seller charges maximum price possible for the buyer. Therefore, the seller will prefer to show the certification if $v_T - c_R > \frac{V}{2}$. In this case, the maximum amount of v_T when the seller does not show the certification now becomes $\frac{V}{2} + c_R$.

Considering this, the buyer now assumes that the range of true quality when the seller doesn't show the certification actually follows $U\left[0,\ \frac{V}{2}+c_R\right]$. In this case, $E(v) = \frac{1}{2}\cdot\left(\frac{V}{2}+c_R\right)$. Now, the seller shows the certification when $v_T - c_R > \frac{1}{2}\cdot\left(\frac{V}{2}+c_R\right)$. Therefore, the maximum amount of v_T when a seller does not show the certification now becomes $\frac{1}{2}\cdot\left(\frac{V}{2}+c_R\right)+c_R$. This strategic consideration can repeat many times until it converges. If this continues for k times, then v_{MAX}, the maximum amount of v_T when the seller does not show the certification, is calculated as follows.

$$v_{MAX}^{k} = \left(\frac{1}{2}\right)^{k}\cdot V + \left\{\left(\frac{1}{2}\right)+\left(\frac{1}{2}\right)^{2}+\left(\frac{1}{2}\right)^{3}+\cdots+\left(\frac{1}{2}\right)^{k-1}\right\}\cdot c_R + c_R$$
$$= \left(\frac{1}{2}\right)^{k}\cdot V + \left\{1-\left(\frac{1}{2}\right)^{k-1}\right\}\cdot c_R + c_R$$

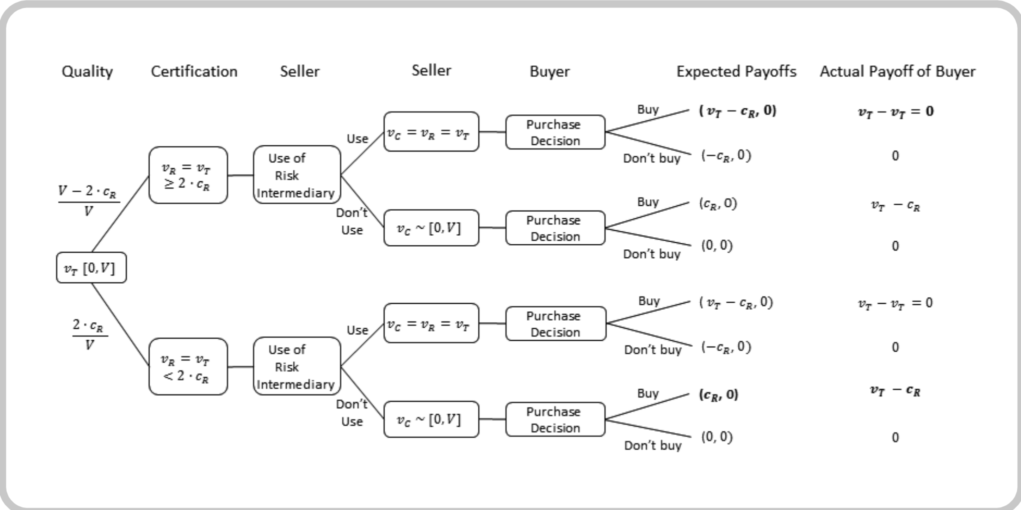
If we assume that both sellers and buyers are strategic and iterate this cognitive process infinitely, then the maximum amount of v_T when a seller does not show the certification can be simplified as follows.

$$\lim_{k=\infty} v_{MAX}^{k} = \lim_{k=\infty}\left[\left(\frac{1}{2}\right)^{k}\cdot V + \left\{1-\left(\frac{1}{2}\right)^{k-1}\right\}\cdot c_R + c_R\right] = 2\cdot c_R$$

Therefore, the buyer finally assumes that the range of true quality actually follows $U[0,\ 2c_R]$ when the seller does not show the certification. In this case, $E(v) = \frac{1}{2}\cdot 2c_R = c_R$ when the seller does not show the certification.

〈Figure 1〉 shows the game tree presenting this result. As the expected payoff for the seller is higher with certification shown when $v_T \geq 2c_R$, and higher without certification when $v_T < 2c_R$, the subgame perfect Nash equilibrium differs according to whether the true value of the product is higher than $2c_R$ or not. More specifically, when $v_T \geq 2c_R$, the subgame perfect Nash equilibrium is that a seller shows certification and a buyer purchases the product, and the seller receives $v_T - c_R$ and the buyer receives 0 from this equilibrium. When $v_T < 2c_R$, the subgame perfect Nash equilibrium is that a seller does not show certification and a buyer still purchases the product, and the seller receives c_R and the buyer receives $v_T - c_R$ from this equilibrium.

Figure 1. The Game Tree of Market Outcomes When the Certification Is 100 Percent Accurate



1.2. Payoffs

From analyzing these equilibria, we can find the average payoff for sellers and buyers when there is 100 percent accurate certification, as follows.

1.2.1. Average Payoff for Seller

$$\pi_S^{100\%} = \left(\frac{V - 2\cdot c_R}{V}\right)\cdot \{\ E(v_T \mid v_T \sim U[\,2\cdot c_R, V\,]) - c_R\} + \left(\frac{2\cdot c_R}{V}\right)\cdot c_R$$

$$= \left(\frac{V - 2 \cdot c_R}{V}\right) \cdot \left(\frac{2 \cdot c_R + V}{2} - c_R\right) + \frac{2 \cdot {c_R}^2}{V}$$

$$= \frac{(V - 2 \cdot c_R) \cdot V}{2V} + \frac{2 \cdot {c_R}^2}{V}$$

$$= \frac{V^2 - 2 \cdot c_R \cdot V + 4 \cdot {c_R}^2}{2V}$$

1.2.2. Average Actual Payoff for Buyer

$$\pi_B^{100\%} = \left(\frac{V - 2 \cdot c_R}{V}\right) \cdot (v_T - v_T) + \left(\frac{2 \cdot c_R}{V}\right) \cdot \{E(v_T \mid v_T \sim U[0, 2 \cdot c_R]) - c_R\}$$

$$= 0 + \left(\frac{2 \cdot c_R}{V}\right) \cdot \left(\frac{2 \cdot c_R}{2} - c_R\right) = 0$$

2. The Market with Inaccurate Certification

2.1. Subgame Perfect Nash Equilibrium

When the certification is 50 percent accurate, the subgame perfect Nash equilibrium differs depending on the expected value of the product perceived by buyers. We have to consider strategic considerations of the buyer, just as we have done in the 100 percent certification case. We can calculate the actual $E(V)$ when sellers do not show the certification through the following process.

When the seller does not show the certification, the buyer first assumes that actual quality can be any value and thus follows $U[0, V]$. In this case, $E(V) = \frac{V}{2}$. Now the expected payoff for the seller is $0.5 \cdot v_T + 0.25 \cdot V - c_R$ when he shows the certification, and $\frac{V}{2}$ when he does not show the certification. Therefore, the seller will show the certification if $0.5 \cdot v_T + 0.25 \cdot V - c_R > \frac{V}{2}$. In this case, the maximum amount of v_T when the seller does not show the certification now becomes $V - \frac{V}{2} + 2 \cdot c_R = \frac{V}{2} + 2 \cdot c_R$. Considering this, the buyer now assumes that the range of true quality actually follows $U\left[0, \frac{V}{2} + 2 \cdot c_R\right]$ when the seller does not show the certification. In this case, $E(V) = \frac{1}{2} \cdot \left(\frac{V}{2} + 2 \cdot c_R\right)$. Now, the seller shows the certification when $0.5 \cdot v_T + 0.25 \cdot V - c_R > \frac{1}{2} \cdot \left(\frac{V}{2} + 2 \cdot c_R\right)$. Therefore, the maximum amount of v_T when seller does not show the certification now becomes $V - V + 4\,c_R = 4\,c_R$. Again, considering this, the buyer now assumes that the range of true quality actually follows $U[0, 4\,c_R]$

when the seller does not show the certification. In this case, $E(V) = \frac{1}{2} \cdot (V - V + 4c_R) = 2c_R$. Now, the seller shows the certification when $0.5 \cdot v_T + 0.25 \cdot V - c_R > 2c_R$. Therefore, the maximum amount of v_T when the seller does not show the certification now becomes $V - 1.5V + 6c_R = -0.5V + 6c_R$.

If this process is iterated k times, then the maximum amount of v_T when the seller does not show the certification becomes

$$v^k_{MAX} = V - 0.5 \cdot k \cdot V + 2 \cdot k \cdot c_R = V - k \cdot (0.5 \cdot V - 2 \cdot c_R)$$

As $v^k_{MAX} \leq V$,

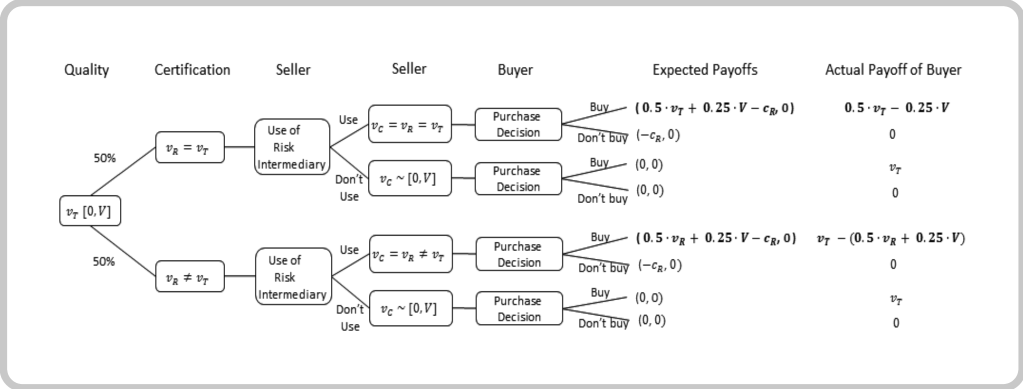
$$V - 0.5 \cdot k \cdot V + 2 \cdot k \cdot c_R \leq V$$

Therefore, we can assume that $0 \leq c_R \leq \frac{1}{4} \cdot V$. Since $0.5 \cdot V - 2 \cdot c_R \geq 0$, v^k_{MAX} will converge to zero when this cognitive process continuously repeats (i.e., as k increases). Therefore, the buyer finally assumes that the range of true quality when the seller does not show the certification is zero. In this case, the expected value when the seller does not show the certification has the following value:

$$E(V) = \frac{1}{2} \cdot 0 = 0$$

The game tree in ⟨Figure 2⟩ explains this result. Here, we consider two different cases according to whether the certification is showing the true quality or not. When the certification is showing the true quality ($v_R = v_T$), the expected payoff for a seller is higher with certification shown. Therefore, the subgame perfect Nash equilibrium is that a seller shows certification and a buyer purchases the product, and the seller receives $0.5 \cdot v_T + 0.25 \cdot V - c_R$ and the buyer receives $0.5 \cdot v_T - 0.25 \cdot V$ from this equilibrium. When the certification is not showing the true quality ($v_R \neq v_T$), the expected payoff for a seller is still higher with certification shown. Therefore, the subgame perfect Nash equilibrium is that a seller shows certification and a buyer purchases the product, and the seller receives $0.5 \cdot v_T + 0.25 \cdot V - c_R$ and the buyer receives $v_T - 0.5 \cdot v_R - 0.25 \cdot V$ from this equilibrium.

Figure 2. The Game Tree of Market Outcomes When the Certification Is 50 Percent Accurate



2.2. Payoffs

From analyzing these equilibria, we can find the average payoff for sellers and buyers when there is 50 percent accurate certification as follows.

2.2.1. Average Payoff for Seller

$$\pi_S^{50\%} = 0.5 \times \{0.5 \cdot E(v_T \mid v_T \sim [0,V]) + 0.25 \cdot V - c_R\}$$
$$+ 0.5 \times \{0.5 \cdot E(v_R \mid v_R \sim [0,V]) + 0.25 \cdot V - c_R\}$$
$$= 0.5 \times (0.5 \cdot 0.5 \cdot V + 0.25 \cdot V - c_R) + 0.5 \times (0.5 \cdot 0.5 \cdot V + 0.25 \cdot V - c_R)$$
$$= \frac{1}{2} \cdot V - c_R$$

2.2.2. Average Actual Payoff for Buyer

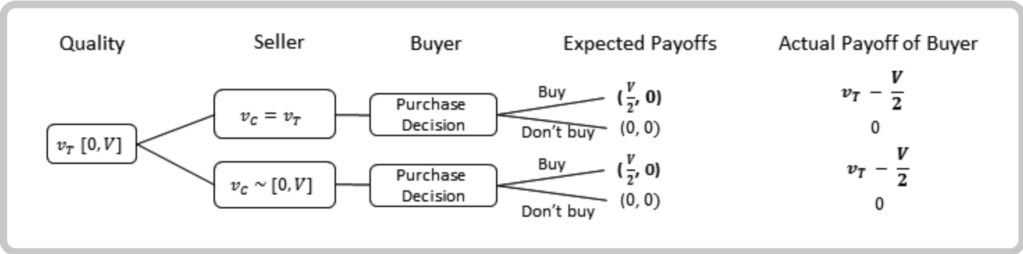
$$\pi_B^{50\%} = 0.5 \times \{0.5 \cdot E(v_T \mid v_T \sim [0,V]) - 0.25 \cdot V\}$$
$$+ 0.5 \times \{E(v_T \mid v_T \sim [0,V]) - 0.5 \cdot E(v_R \mid v_R \sim [0,V]) - 0.25 \cdot V\}$$
$$= 0.5 \times \{0.5 \cdot 0.5 \cdot V - 0.25 \cdot V\} + 0.5 \times \{0.5 \cdot V - 0.5 \cdot 0.5 \cdot V - 0.25 \cdot V\} = 0$$

3. The Market without Certification

3.1. Subgame Perfect Nash Equilibrium

When there is no certification, a seller simply charges $\frac{V}{2}$ and a buyer purchases it, and the seller receives $\frac{V}{2}$ and the buyer receives $v_T - \frac{V}{2}$, as is shown in 〈Figure 3〉.

Figure 3. The Game Tree of Market Outcomes without Certification



3.2. Payoffs

From this market outcome, we can find the average payoff for sellers and buyers when there is no certification as follows.

3.2.1. Average Payoff for Seller

$$\pi_S^{No\ Certification} = \frac{V}{2}$$

3.2.2. Average Actual Payoff for Buyer

$$\pi_B^{No\ Certification} = E(v_T \mid v_T \sim [0, V]) - \frac{V}{2}$$

$$= \frac{V}{2} - \frac{V}{2} = 0$$

IV. Market Outcomes

The results of the model analysis can be summarized as in ⟨Table 1⟩.

Table 1. Payoffs for Sellers and Buyers

	Average Payoff for Sellers	Average Actual Payoff for Buyers
Certification is 100% accurate	$\frac{V^2 - 2 \cdot c_R \cdot V + 4 \cdot c_R^2}{2V}$	0
Certification is 50% accurate	$\frac{1}{2} \cdot V - c_R$	0
There is no certification	$\frac{1}{2} \cdot V$	0

From this result, we can come up with the following implications about the profit patterns of sellers and buyers according to the accuracy of certification.

1. Seller's Profit

First, the relationship between the payoff under 100 percent certification and under 50 percent certification is as follows.

$$\pi_S^{100\%}-\pi_S^{50\%}=\frac{V^2-2\cdot c_R\cdot V+4\cdot c_R^2}{2V}-\frac{1}{2}\cdot V+c_R$$
$$=\frac{V^2-2\cdot c_R\cdot V+4\cdot c_R^2-V^2+2\cdot V\cdot c_R}{2V}$$
$$=\frac{4\cdot c_R^2}{2V}=\frac{2\cdot c_R^2}{V}\geq 0$$

Therefore, the payoff for a seller under 100 percent certification is higher than the payoff for a seller under 50 percent certification.

Second, the relationship between the payoff under 50 percent certification and no certification is as follows.

$$\pi_S^{50\%}-\pi_S^{No\ Certification}=\frac{1}{2}\cdot V-c_R-\frac{1}{2}\cdot V=-c_R\leq 0$$

Therefore, the payoff for a seller under 50 percent certification is lower than the payoff for a seller under 0 percent certification.

Third, the relationship between the payoff under 100 percent certification and no certification is as follows.

$$\pi_S^{100\%}-\pi_S^{No\ Certification}=\frac{V^2-2\cdot c_R\cdot V+4\cdot c_R^2}{2V}-\frac{1}{2}\cdot V$$
$$=\frac{V^2-2\cdot c_R\cdot V+4\cdot c_R^2-V^2}{2V}$$
$$=\frac{-c_R\cdot V+2\cdot c_R^2}{V}=\frac{c_R\cdot(2\cdot c_R-V)}{V}\leq 0$$
$$(\because\ 0\leq c_R\leq 0.25\cdot V)$$

Therefore, the payoff for a seller under 100 percent certification is always lower than the payoff for a seller under no certification.

From this result, we can find the relationship between payoffs for sellers as follows:

$$\frac{1}{2}\cdot V\geq\frac{V^2-2\cdot c_R\cdot V+4\cdot c_R^2}{2V}\geq\frac{1}{2}\cdot V-c_R$$
$$\therefore\ \pi_S^{No\ Certification}\geq\pi_S^{100\%}\geq\pi_S^{50\%}$$

Therefore, the analytic model predicts that the payoff for sellers without certification is the highest, and the payoff for sellers with 100 percent certification is higher than the payoff for sellers with 50 percent certification. We can see that the major factor explaining this difference is the cost of certification (c_R), as the seller profit will be the same in all three conditions if the cost of certification is zero (i.e., if c_R = 0).

We believe this originates from the assumptions that buyers are all risk-neutral and that sellers and buyers are strategic. More specifically, a strategic and risk-neutral buyer considers the cost of certification when predicting the seller behavior and calculating the expected value of the product, and a strategic seller maximizes profit by charging the highest price possible according to the buyer's expected value. Therefore, the cost of certification affects both the seller's information disclosure and the buyer's expected value calculation, ultimately leading to a decrease in seller's profit when certification is available. Moreover, as 50 percent certification causes more uncertainty than 100 percent certification in terms of predicting the effect of certification cost, the seller's expected profit is lower with 50 percent certification than with 100 percent certification. This explains why seller profit is the highest with no certification and the lowest with 50 percent certification.

2. Buyer's Profit

As is shown in 〈Table 1〉, the payoff for a buyer will always be zero regardless of the accuracy of certification (i.e., $\pi_S^{100\%} = \pi_S^{50\%} = \pi_S^{No\ Certification} = 0$) as a monopolistic seller charges flexible price up to the buyer's expected payoff and maximizes profit. Again, this is because we assume that buyers are all risk-neutral and both sellers and buyers are completely strategic, so that the seller can precisely measure the buyer's willingness to pay and charges the maximum price.

Ⅴ. Discussion

In this study, we have tried to determine the effect of inaccurate quality signaling on various market outcomes such as seller profit and buyer profit through a game theoretic model. After examining market equilibria under several types of quality signaling, our analytic model has predicted that seller profit will be the lowest with inaccurate certification and the highest with no certification mostly due to the certification cost, and that buyer profit will be zero across all conditions. Although people generally believe that signaling quality helps sellers, the model suggests that there might be no need to use certification in a market under information asymmetry when there exists a certain level of certification cost. More implications regarding this counterintuitive result are as follows.

First, it is important to note that inaccurate certification might be worse for sellers than accurate certification. Therefore, if sellers or policy makers plan to introduce quality signaling mechanism in the market, it should be reliable enough so that customers do not get confused about any information from the quality signals. If any quality certification is less than accurate due to possible reasons mentioned above (bias, conflict of interest, incompetency, etc.), sellers should then proceed with caution. This result may also warn a small number of sellers who attempt to manipulate the certification system to increase short-term profit, as any errors in the certification system will eventually work against them. Second, certification cost plays an important role in determining the effect of certification on market outcomes. According to our analysis, the main factor affecting the effect of certification is the cost of certification, and seller profit will be the same across all three conditions if the cost of certification is zero. As certifiers usually charge non-negligible cost in real market situations, the effect of certification cost should be carefully considered when sellers make certification decisions. Third, buyers' risk attitude should be more carefully investigated in understanding how certification affects market outcomes. Our analysis basically assumes that buyers are all risk-neutral and do not vary in their risk propensities, and this is possibly the main reason why no certification is found to be better for sellers than any certification; risk-neutral buyers may not appreciate sellers' quality signaling very much. However, most empirical studies that have estimated the risk attitudes of customers, such as Binswanger (1980), generally show that there exist more risk-averse customers than risk-taking customers. Therefore, the assumption of risk neutrality should be re-considered to better understand the effect of quality signaling in a market under information asymmetry.

These implications can be easily applied to a recent issue of StockX, an online marketplace which offers quality certifications for sneakers. In 2022, several reports confirmed that Nike challenged StockX for certifying several fake sneakers as being authentic. While the legitimacy of their certification system is still being debated among many sellers and buyers, if their accuracy is continuously challenged, the sellers will not benefit from using their certification system even though the system ends up overstating the qualities their products. Therefore, when quality certification is inaccurate, not only the buyers but also the sellers will shift to other marketplaces where no certification mechanism is offered.

Overall, we believe our results provide meaningful implications to the literature on information disclosure by showing how the accuracy of certification and its costs affect market outcomes. Sellers or policy makers can also learn from the findings of this paper on how to carefully consider the quality of signaling before utilizing it to mitigate information asymmetry. Future research should work on the limitations of this study and extend the findings of our primary analytical model in several directions, such as observing market or experimental data, considering risk-averse buyers, applying varying levels of certification cost, and relaxing monopoly and examining the effect of competitive sellers.

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