Certification under Oligopolistic Competition

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Abstract

In a symmetric duopolistic market where each firm's choice regarding certain quality attributes such as the environmental friendliness of its product is its own private information, the extent of horizontal differentiation between firms plays a crucial role in a certifier's optimal certification policy. Under a non-profit certifier it is always the case that both firms produce the highest quality and opt for certification. This is also the case under a for-profit certifier, but only when the degree of horizontal differentiation is sufficiently high. When horizontal differentiation is low, the for-profit certifier, by charging a very high certification fee, creates maximum vertical differentiation between firms. As a result, only one firm produces the highest quality and opts for certification whereas the other firm produces the lowest quality and does not opt for certification. This asymmetry under a for-profit certifier makes the market inefficient, which provides one possible explanation for the existence of mostly non-profit certifiers in such markets.

Keywords : Asymmetric Information, Certification, Eco-labeling, Horizontal Differentiation, Oligopolistic Competition

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1 Introduction

Quality attributes such as the environmental friendliness of a product have drawn significant attention in recent years among consumers and economists alike. The key feature of such attributes is that a firm usually knows the actual level of such quality attributes of the good it is producing, but its rival firms and consumers do not. This creates an information asymmetry among various agents in such markets. Examples of such unobservable quality attributes are - the amount of pesticides used during a good's production process, amount of pollution caused, involvement of any child labor, etc. This asymmetry has led to the emergence of a particular type of market institution called a certification intermediary. These act as middlemen who send some information regarding quality attributes of privately informed agents (firms) to uninformed parties (consumers). These intermediaries can be for-profit firms or non-profit firms. Curiously enough, while financial markets are dominated by for-profit certifiers, the markets in consideration are highly populated with non-profit certifiers (government agencies or NGOs). For example, the European Eco-Management and Audit Scheme (EMAS) certification is given either by the state or by the organizations and professionals authorized by the state to the firms who voluntarily commit to perform according to EMAS regulations on environmental commitments[1], and the Forest Stewardship Council (FSC) is an international non-profit organization responsible for standard setting, independent certification and labeling of forest products, which offers customers around the world the ability to choose products from socially and environmentally responsible forestry, etc. Therefore, it seems quite natural to discover what role for-profit certifiers could play in providing certification for these environmentally friendly products.

In the literature, these unobservable quality attributes, such as - environmental friendliness of a product, or certain social attributes of a product, are considered as vertical attributes, as evidence suggests that consumers are willing to pay more for products with higher levels of these attributes[2]. In these markets, firms compete with each other by choosing their own quality attributes along vertical dimensions, deciding whether to get their products certified or not and setting prices. But along with this vertical dimension, there also exists a horizontal differentiation between firms, such as firms' locations or consumers' individual taste preferences for different firms.

In this paper, I study how an exogenous degree of horizontal product differentiation and the objective function of a certifier (for-profit or non-profit) affect the equilibrium of the market. More precisely, I take the horizontal

[1]The EMAS is a voluntary environmental management instrument, which was developed by the European Commission. It enables organizations to assess, manage and continuously improve their environmental performance. The scheme is globally applicable and open to all types of private and public organizations. In order to register with EMAS, organizations must meet the requirements of the EU EMAS-Regulation.

[2]Consumers are willing to pay more for products with "Dolphin-safe" labels (Teisl et al., 2002), organic and fair trade coffee in the UK (Galarraga and Markandya, 2004), and sportswear made of organic cotton that involves lower use of pesticides and fertilizers (Casadesus-Masanell et al., 2009).

differentiation between firms to be fixed and given, and then ask the following two questions : how does the horizontal differentiation between firms influence a certifier's (for-profit or non-profit) certification policy and therefore influences firms' decisions regarding their quality choices and decisions to opt for certification? Secondly, would a social planner choose a for-profit certifier or a non-profit certifier for a given market?

To answer the questions I consider a market where two firms are horizontally differentiated and the degree of this differentiation is fixed and known. There is a certifier (for-profit or non-profit) in the market who announces its certification policy. Each firm chooses the quality it will produce which is its own private information, decides whether to opt for certification or not and sets a price. Consumers are willing to pay more for a higher quality product which is more costly to produce but generates higher surplus.

I find that under a non-profit certifier which certifies the highest quality products only, it is always the case that both firms produce the highest quality and opt for certification. This is also the case under a for-profit certifier but only when the degree of horizontal differentiation is sufficiently high. When horizontal differentiation is low, the for-profit certifier, by charging a very high certification fee, creates maximum vertical differentiation between firms. As a result, only one firm produces the highest quality and opts for certification whereas the other firm produces the lowest quality and does not opt for certification. This asymmetry makes the market inefficient under a for-profit certifier. Therefore, a social planner who wants to maximize social welfare would weakly prefer to have a non-profit certifier rather than a for-profit certifier to operate in such a market.

The intuition behind this is the following : a for-profit certifier cares only about its profit. In order to do so, when the horizontal differentiation between firms is low, by charging a very high fee the certifier creates maximum vertical differentiation between firms and captures a large amount of surplus from the market. When this horizontal differentiation becomes high, both firms capture sufficient monopoly power over their respective market shares which forces the certifier to reduce its fee. As a result, both firms produce the highest quality and opt for certification. Therefore, the degree of horizontal differentiation between firms plays a crucial role when a for-profit certifier chooses its certification policy and which in turn determines the nature of market equilibrium - whether it will be symmetric or asymmetric. The asymmetric equilibrium is inefficient due to the fact that firms share the market unequally and the lowest quality products are being traded in the market.

In industrial organization theory, my paper relates to the vast literature discussing endogenous price-quality competition[3]. However, this deals with either search goods or experience goods and does not address the issue of certification. I discuss the impact of having a certifier in a market where firms are involved in price-quality competition[4]. Lizzeri (1999) studies the profit maximizing policy of certifier(s) when a firm's quality is exogenous. He

[3]Rosen (1974), Shapiro (1982), Chan & Leland (1982), Wolinsky (1983), Dubovik & Janssen (2012), etc.

[4]My model fits to the markets for credence goods. But as I consider a single shot game, theoretically it can also be applied to the

finds that a monopolist certifier can extract a large amount of surplus without revealing any information, whereas if there are more than two certification agencies, there is a set of equilibria in which at least two certifiers reveal all the information and charge zero fees, making zero profits. Based on a similar framework, Albano and Lizzeri (2001) endogenize the monopolist seller's quality choice. They find different ways to implement the certifier's optimal policy, such as full disclosure with a nonlinear price schedule or a fixed fee with noisy disclosure. They also find that the certifier just needs to manipulate one dimension to obtain the optimal policy, either the price schedule or the disclosure policy. I introduce competition between the production firms. I find the optimal certification policy for a for-profit certifier. I study how competition between the production firms affects its optimal policy, and characterize the market equilibrium and present a comparative analysis between a for-profit certifier and a non-profit certifier. Interestingly, I find that under a for-profit certifier depending on the extent of horizontal differentiation between firms, both the symmetric and the asymmetric equilibrium can arise, whereas under a non-profit certifier only the symmetric equilibrium arises. The asymmetric equilibrium under a for-profit certifier makes the market inefficient.

My paper also relates to the literature on 'Eco-labeling' in environmental economics. Mason (2006) analyzes the welfare implications of third party eco-labeling as an imperfect and costly signal of quality. Bakshi & Bose (2007) analyze the optimality of different labeling policies (self labeling and third party labeling) for credence goods when firms can cheat with respect to the labels they affix on their products. Bonroy & Constantatos (2008) study firms' behavior under perfect labeling and imperfect labeling and compare them from an efficiency point of view. Baron (2011) studies the choice of a credence standard by the firms forming a credence organization and explains how social pressure affects the standard they choose. He finds that the credence standard is lower the larger the organization, and social pressure results in a higher standard. I examine the role of a horizontal differentiation dimension between firms on a for-profit certifier's optimal certification policy in such a market and compare the efficiency of the respective market equilibrium to that with the market equilibrium under a non-profit certifier. I find that under certain reasonable assumptions, it is socially optimal to have a non-profit certifier in such a market and is weakly preferable than having a for-profit certifier.

The paper is organized as follows: in the next section I describe the model, in section 3 I present a basic result and discuss the beliefs of different agents about firms' quality choices. I characterize the market equilibrium under a non-profit certifier in section 4. I find the optimal certification policy for a for-profit certifier and characterize the market equilibrium under such a policy in section 5, followed by a welfare comparison in section 6. The final section concludes. The proofs of the propositions are described in the appendix along with the solution of the

markets for experience goods.

for-profit certifier's maximization problem.

2 Model

Consider a market that is comprised of a certifier, two identical firms - 1 and 2, and a unit mass of consumers. The certifier can be a for-profit firm or a non-profit firm. Competition between firms has two dimensions - horizontal and vertical. The horizontal dimension is fixed and known to everybody, and I model it by the Hotelling line. Consumers are located uniformly on a line of unit length, and firms 1 and 2 are located on the same line at the two extreme points 0 and 1 respectively. In order to buy, a consumer has to incur a quadratic transportation cost of $t \cdot d^2$, $t > 0$, where d is the distance between that consumer and the firm from which he buys the product. The vertical dimension is modeled through firms' quality choices. Firm i can produce any quality $\theta_i \in [0, \bar{\theta}]$ at a unit cost of $c(\theta_i)$ for $i = 1, 2$, with $c(\theta)$ being increasing in θ, for $\theta \in [0, \bar{\theta}]$, and $c(0) > 0$. This choice of quality by a firm is its own private information, that is, whatever quality a firm produces is only observed by that particular firm. It is neither observed by its rival firm nor by any of the consumers.[5] Consumers have unit demand. If consumers know the quality of a product, they are willing to pay $V(\theta)$ for a product of quality θ, with $V(\theta)$ being increasing in θ. Let $S(\theta) = V(\theta) - c(\theta)$ for $\theta \in [0, \bar{\theta}]$ and assume that $S(\theta)$ is increasing in θ, with $S(0) > 0$. I use the following notations: $w(\theta) = S(\theta) - S(0)$, the incremental surplus for quality θ, for $\theta \in [0, \bar{\theta}]$, and $K = S(\bar{\theta}) - S(0)$, the maximum incremental surplus. Clearly $w(\theta)$ is also increasing in θ.

The certifier announces a certification policy which consists of a disclosure rule (D) and a non-negative certification fee (F). If a firm applies for certification, it has to pay the certification fee F to the certifier. I assume that if a firm applies for certification, the certifier can observe that particular firm's quality choice perfectly and it certifies the firm according to D. In order to maintain credibility in the market, I assume that the certifier cannot lie or cheat[6]. Formally, a fee $F : [0, \bar{\theta}] \to \mathbb{R}_+ \bigcup \{0\}$ and a disclosure rule $D : [0, \bar{\theta}] \to \mathbf{Q}$, where $\mathbf{Q}$ is the set of probability distributions on real numbers. For example, a policy in which only the highest quality is certified can be represented by a function that maps quality $\bar{\theta}$ to a probabilty distribution degenerate at $\bar{\theta}$ and it maps any other quality level (say θ) to a probabilty distribution degenerate at r independent of θ.

[5]The reasons that I take the horizontal differentiation between firms to be given and allow each firm to choose its quality are the following. First of all, a firm's location choice is a long term decision and is difficult to change. Secondly, the environmental friendliness of a product has drawn significant attention only in recent times. Before that, firms were already selling their products without any reference to such quality attributes and over time, consumers have developed their own taste preferences for individual firms which cannot be changed suddenly. In most of the cases, environmental friendliness of a product is a voluntary commitment of a firm. Therefore, given these existing individual preferences of consumers for firms, I allow each firm to decide whether to produce an environmentally friendly product or not.

[6]There are some works which address the issue of credibility of these certification intermediaries. See Strausz (2005), Mathis, McAndrews & Rochet (2009), Peyrache & Quesada (2011).

In different markets, we often find that a non-profit certifier certifies products of the highest quality only and charges a very small fee. For example, it certifies a product only if it finds that there is no child labor involved during its production process, or it certifies a product as a 'Green product' or 'Eco-friendly product' only if it finds that no pesticide is used or it satisfies certain environmental emission standards during its production process. Basically a non-profit certifier cares so much about the negative externalities caused by any quality level which is lower than the highest that it certifies products of the highest quality only. For this reason, I consider that the objective of a non-profit certifier is to maximize the number of firms producing the highest quality. Therefore, in my model a non-profit certifier certifies products of quality $\bar{\theta}$ only. On the other hand, a for-profit certifier cares only about its profit and it chooses the certification policy (F, D) in such a way that its profit is maximized. To compare welfare between the cases under a for-profit and a non-profit certifier, I introduce a social planner who wants to maximize social welfare which I measure in terms of total surplus.

The timing of the game is as follows:

1. At the first stage the certifier announces its certification policy (F, D).

2. Observing this certification policy, firms simultaneously choose qualities (θ_1, θ_2) that they will produce (this quality choice is each individual firm's private information) and decide whether to apply for certification or not. If a firm decides to apply for certification, it pays the fee F to the certifier. The certifier inspects the quality of that particular firm and announces its inspection result (R) for that firm publicly according to D.

3. After observing the certification results R (if any), firms choose prices (P_1, P_2) simultaneously.

4. At the final stage of the game, consumers observe the certification policy, certification results R (if any) and the prices charged by the firms. They consider their transportation costs and decide whether to buy and if so, which firm to buy from.

As each firm's quality choice is its private information, at stage 3 while setting prices, each firm forms an expectation regarding its rival firm's quality choice based on the information available (certification policy and certification result). Let $\theta^e_{i,r}$ denote the expected quality of firm i as perceived by its rival firm, where $\theta^e_{i,r} = \mathbb{E}[\theta_i \mid (F, D), R]$, for $i = 1, 2$. Similarly, at stage 4 while making buying decisions, consumers also form expectations about each firm's quality choice based on the information available (certification policy, certification results and prices) to them. Let θ^e_i denote the expected quality of firm i as perceived by the consumers where $\theta^e_i = \mathbb{E}[\theta_i \mid (F, D), R, P_1, P_2]$, for $i = 1, 2$.

The price chosen by firm i is denoted by P_i. If firm i chooses to produce quality θ_i, without loss of generality I can restrict its pricing strategy set to the interval $[c(\theta_i), V(\bar{\theta})]$, for $i = 1, 2$.

The payoff of each firm is its net profit. The payoff of a for-profit certifier is the total fee(s) it gets from the firm(s) who applies for certification.

The payoff of a consumer who buys is his net surplus. If he buys the product from firm i, then his payoff is the valuation of the product with quality θ_i^e minus the price charged by firm i minus the transportation cost that he incurs to reach firm i. If he knows through certification that the true quality of the product firm i is θ (e.g., in case of a non-profit certifier if a consumer sees that firm i's product is certified, he knows that its quality must be equal to $\bar{\theta}$), then $\theta_i^e = \theta$, and therefore, from buying the product from firm i his payoff is equal to the valuation of the product with quality θ minus the price charged by that firm minus the transportation cost he incurs to reach the firm. If he does not buy, his payoff is zero.

The equilibrium notion that I use is pure strategy Nash equilibrium.

3 Preliminary Result and Beliefs

Before moving to the main analysis, it would be helpful to understand how a firm will behave when there is no certifier in the market. This will help in my model to study a firm's behavior when it does not apply for certification. Lemma 1 describes firms' behavior in the absence of any certifier, which along with the out of equilibrium beliefs of firms and consumers, discussed after lemma 1, significantly simplifies the analysis of the whole problem.

Lemma 1. *When there is no certifier in the market, there is no equilibrium where either of the firms produce strictly positive quality.*

Proof. Suppose on the contrary that in equilibrium one of the firms, say firm 1, produces a positive quality $\theta_1^*(>0)$ and sets a price P_1^*. This quality choice is neither observed by firm 2, nor by consumers. If firm 1 deviates by choosing some other quality, this deviation will also not be observed by firm 2 and consumers. So whatever profit firm 1 makes by choosing quality θ_1^* and charging price P_1^*, it can always make more profit by choosing quality $\theta_1^* - \varepsilon$, where $\varepsilon > 0$, and charging the same price P_1^*, as $c(\theta_1^* - \varepsilon) < c(\theta_1^*)$. This is true for any positive quality θ_1^*. Therefore, whenever firm 1 chooses some positive quality, deviation to lower quality is always profitable to firm 1, which contradicts our assumption. Therefore in equilibrium, firm 1 will not produce any positive quality. By symmetry, the same is also true for firm 2, which completes the proof. □

Suppose a certifier announces it will certify a certain quality θ(say) only. If in equilibrium a firm (say firm i) does not apply for certification, its rival firm and consumers cannot observe its quality. In such a case, in equilibrium it can never happen that firm i produces positive quality. Because if it does so and charges a price P_i^*, it can always make more profit by lowering its quality and charging the same price P_i^*. Following a similar argument to that mentioned in lemma 1, irrespective of the price that firm i charges, its optimal quality choice is to produce quality 0.

For a firm i to apply for certification can only be a part of its equilibrium strategy if it has no incentive to deviate. If it deviates by not applying for certification, then its quality will not be observed. Therefore, irrespective of whatever out of equilibrium beliefs that its rival firm and consumers may have about its quality choice, its most profitable quality choice would be always to produce quality 0. However, these out of equilibrium beliefs play a role in a firm's pricing decision. For any out of equilibrium beliefs which assign any positive probabilty on firm i producing any positive quality will imply that the firm could charge higher price. But it does not make much sense to assign such beliefs, as a firm's cost function is common knowledge and therefore, its rival firm and consumers can draw inferences about its most profitable quality choice decision. Therefore, to make the deviation for a certified firm to not apply for certification not profitable, I assume that its rival firm and consumers will have the most pessimistic out of equilibrium beliefs about the deviating firm's quality choice, that is, they will all believe the deviating firm's quality to be 0, *i.e.*, $\theta_{i,r}^e = 0$ and $\theta_i^e = 0$ respectively, which is also the most reasonable one.

4 Non-profit Certifier

Certification Policy: As a non-profit certifier wants to maximize the number of firms producing the highest quality, consider the following certification policy (F, D) announced by the non-profit certifier: the certification fee $F = 0$ and the disclosure rule D states that it certifies products of quality $\bar{\theta}$ only.[7] Given this certification policy, I find firms' optimal behavior.

Firms' Behavior: Suppose given this certification policy, in equilibrium both firms produce quality $\bar{\theta}$ and apply for certification. Therefore through certification results, at the price setting stage firms know each other's quality choice and before buying consumers also know both firms' quality choices. Due to price competition, each of the two firms will set prices equal to $P_1^* = P_2^* = c(\bar{\theta}) + t$, capture half of the market, and make a profit of $\frac{t}{2}$.

Deviations: Now given the quality choices made by each of the firms, no firm has an incentive to deviate by charging a different price. At the quality choice stage, a firm could deviate by not applying for certification. If it does so, its quality will not be observed by others. Therefore, its most profitable quality choice would be to produce quality 0.

[7]For a small certification fee, the results do not change.

Suppose one firm (say firm 1) deviates by producing quality 0 and not applying for certification. In such a case, its rival firm and consumers will believe $\theta^e_{1,r} = 0$ and $\theta^e_1 = 0$. Considering these most pessimistic out of equilibrium beliefs, firm 1 will set a different price and will face a demand $\frac{(3t-K)}{6t}$, and its deviational profit will be $\frac{(3t-K)^2}{18t}$ (for details see Appendix). Clearly, the deviating firm will have positive demand only if $t > \frac{K}{3}$. The deviation will not be profitable for either of the firms, if the equilibrium profit is greater than or equal to the deviational profit, that is, if $\frac{t}{2} - \frac{(3t-K)^2}{18t} \geq 0 \iff t \geq \frac{K}{6}$. If $t < \frac{K}{6}$, this deviation could be profitable, but the deviating firm will have a positive demand only if $t > \frac{K}{3}$, which contradicts the condition $t < \frac{K}{6}$. For $t \leq \frac{K}{3}$, the deviating firm will face no demand and will make zero profit. Hence, this deviation is never profitable for either firm.[8]

Note that, the situation where both firms produce quality 0 and do not opt for certification can never be part of equilibrium. As $S(\bar{\theta}) > S(0)$ and given one firm produces quality 0 and does not opt for certification, the other firm's best response would be to produce quality $\bar{\theta}$ and apply for certification. The minimum price that the non certified firm can charge is $c(0)$. The certified firm can capture the entire market by charging a price marginally lower than $V(\bar{\theta}) - [V(0) - c(0)] - t$. In such a situation the certified firm could earn a surplus of $K - t$ and the non-certified firm earns nothing. Therefore, the strategies where both firms produce quality 0 and do not apply for certification can never be part of equilibrium. Hence, we have the following proposition.

Proposition 1. *If a non-profit certifier certifies products of quality $\bar{\theta}$ only and charges no certification fee, there is an equilibrium which is unique and symmetric where both firms produce quality $\bar{\theta}$, opt for certification, set prices equal to $c(\bar{\theta}) + t$ and each firm captures half of the market. Each firm makes a profit of $\frac{t}{2}$.*

Under a non-profit certifier, I find that in equilibrium both firms always produce the highest quality and opt for certification. Intuitively this is clear, because as the highest quality generates maximum surplus and there is no (or only a very small) certification fee, both firms want to extract maximum surplus by producing the highest quality and revealing its true quality to consumers through certification. As horizontal differentiation increases, firms' profits also increases. But under a for-profit certifier, this may not be the case.

Remark. In a situation where horizontal differentiation vanishes (i.e., $t = 0$), the above strategies of firms men-

[8] In the case where the non-profit certifier charges a very small fee ε for certification, if both firms opt for certification by producing the highest quality, then each firm will make a profit of $\frac{t}{2} - \varepsilon$. Again, if a firm deviates by not applying for certification, it will produce quality 0. This deviating firm will have positive demand only if $t > \frac{K}{3}$. For $t > \frac{K}{3}$, the deviation will not be profitable if $\frac{t}{2} - \varepsilon \geq \frac{(3t-K)^2}{18t} \iff \varepsilon \leq \frac{K(6t-K)}{18t}$. The RHS of the inequality is non-negative for $t \geq \frac{K}{6}$. Hence for $t \geq \frac{K}{6}$, the certifier can charge a small certification fee ε such that $\varepsilon \leq \frac{K(6t-K)}{18t}$ and both firms will produce the highest quality and opt for certification. For $t \leq \frac{K}{6}$, the deviating firm will make zero profit because it will face zero demand. Hence for $t \leq \frac{K}{6}$, the certifier can charge a small certification fee ε such that $\varepsilon \leq \frac{t}{2}$ and both firms will produce the highest quality and opt for certification. As long as the non-profit certifier charges a small certification fee satisfying certain conditions to certify the highest quality only, it is always the case that both firms will produce the highest quality and will opt for certification.

tioned in proposition 1 will still remain equilibrium strategies, as long as the certifier does not charge a certification fee. Due to perfect competition, both firms will set prices equal to the marginal cost ($= c(\bar{\theta})$), will make zero profits and the entire surplus will go to consumers. In this perfect competition case, along with this symmetric equilibrium where both firms produce quality $\bar{\theta}$ and opt for certification, there also exists an asymmetric equilibrium where one firm produces quality $\bar{\theta}$ and opts for certification, whereas the other firm produces quality 0 and does not opt for certification. As $S(\bar{\theta}) > S(0)$, the certified firm has a competitive advantage over the non-certified firm. By charging a price marginally lower than $V(\bar{\theta}) - [V(0) - c(0)]$ the certified firm can capture the entire market. Therefore, in equilibrium, the certified firm charges a price equal to $V(\bar{\theta}) - [V(0) - c(0)]$ and sells to all consumers. The non-certified firm makes zero profit whereas the certified firm earns a surplus of K. For any positive certification fee, if both firms opt for certification, due to perfect competition prices will still be equal to the marginal cost ($= c(\bar{\theta})$) and both firms will make losses. Hence, when $t = 0$, for any positive certification fee (for-profit or non-profit), only the asymmetric equilibrium will exist.

5 For-profit Certifier

In this section I derive the optimal certification policy for a for-profit certifier. A for-profit certifier wants to extract maximum surplus from the market, and it does so by charging a suitable positive fee F for certifying a certain quality. First I will consider the certification policy announced by a for-profit certifier to be exogenously given. That is, given that the certifier charges a fee F to certify a certain quality θ(say), $\theta \in [0, \bar{\theta}]$, I find conditions for an equilibrium in which both firms produce quality θ and opt for certification (a 'symmetric case'), and conditions for an equilibrium in which only one firm produces quality θ and opts for certification whereas the other firm does not opt for certification (an 'asymmetric case'). Later I endogenize the certification policy and find the optimal certification policy for a for-profit certifier and characterize the market equilibrium.

5.1 *Firms' Behavior*

Symmetric case

Proposition 2. *For a given certification policy (F_s, D), where D states that the certifier will certify products of quality θ only, $\theta \in [0, \bar{\theta}]$, there is an equilibrium which is unique and symmetric where both firms produce quality θ and apply for certification, provided $F_s \leq \frac{w(\theta)(6t - w(\theta))}{18t}$.*

Given the certification policy mentioned in proposition 2, if both firms produce quality θ and apply for certification by paying the fee F_s to the certifier, in equilibrium firms charge prices $P_1^* = P_2^* = c(\theta) + t$. Each of the firms faces a demand equal to $\frac{1}{2}$ and earns a profit of $\frac{t}{2} - F_s$ each.

Now given the certification policy, strategies taken by one firm and those taken by the other in stage 2, the optimal price for the other firm is $c(\theta)+t$. Deviation to a different price is never profitable.

Each of the firms can deviate only in stage 2. Clearly neither firm will deviate by producing quality that is higher than the certified quality and applying for certification, because by producing higher quality it will incur higher cost. But through certification its quality will be revealed as θ. So it will make less profit than equilibrium profit due to the higher cost of production. Hence this deviation is not profitable for either firm. If a firm deviates by producing quality less than θ, the certifier will not certify its quality. In that case, the deviated firm will not apply for certification. Now if one of the firms deviates by not applying for certification, the other firm and the consumers will not know its quality. In that case the best possible quality choice for the deviating firm will be to produce quality 0. To make this deviation not profitable, I assume that its rival firm and consumers will have the most pessimistic out of equilibrium beliefs about the deviated firm's quality choice, that is, they will believe its quality to be 0. If either of the firms (say firm 1) deviates by producing quality 0 and not applying for certification, then incorporating the beliefs of its rival firm (*i.e.*, $\theta^e_{1,r} = 0$) and the consumers (*i.e.*, $\theta^e_1 = 0$) we can find its optimal deviating price. This deviation will not be profitable if the fee F_s charged by the certifier is not high (see Appendix).

The certifier wants to maximize $\frac{w(\theta)(6t-w(\theta))}{18t}$ with respect to θ which is equivalent to maximizing $\frac{w(\theta)(6t-w(\theta))}{18t}$ with respect to $w(\theta)$, as $w(\theta)$ is monotonically increasing in θ. The solution of the maximization problem $\hat{\theta}$ is given by $\hat{\theta} = w^{-1}(\widehat{w(\theta)})$, where

$$\widehat{w(\theta)} = \begin{cases} w(\bar{\theta}), & if\, w(\bar{\theta}) \leq 3t \\ 3t, & if\, w(\bar{\theta}) > 3t \end{cases}.$$

Therefore the certifier could certify products of quality $\hat{\theta}$ only and charges a certification fee $\hat{F}_s$, where $\hat{F}_s = \frac{w(\hat{\theta})(6t-w(\hat{\theta}))}{18t}$. Given this certification policy, both firms produce quality $\hat{\theta}$ and opt for certification.

Asymmetric case

Proposition 3. *For a given certification policy (F_a, D), where D states that the certifier will certify products of quality θ only, $\theta \in [0, \bar{\theta}]$, there is an equilibrium which is unique and asymmetric where one firm produces quality θ and applies for certification whereas the other firm produces quality 0 and does not apply for certification, provided* $\frac{w(\theta)(6t-w(\theta))}{18t} \leq F_a \leq \frac{w(\theta)(6t+w(\theta))}{18t}$.

Given the certification policy in proposition 3, suppose in equilibrium one firm (say firm 1) produces quality 0 and does not apply for certification, whereas the other firm (firm 2) produces quality θ and applies for certification. Firm 2 has several deviation possibilities, but following a similar argument to that in proposition 2, the most profitable deviation for firm 2 would be to produce quality 0 and not apply for certification. To have this deviation not profitable for firm 2, F_a should not be too high. Among all possible deviations for firm 1, the best possible deviation is to produce quality θ and apply for certification. This deviation is not profitable for firm 1 if F_a is sufficiently high (see Appendix).

The certifier wants to maximize F_a. Note that F_a is increasing in θ and attains its maximum at $\theta = \bar{\theta}$. Therefore the certifier can certify products of quality $\bar{\theta}$ only and can charge a fee $\hat{F}_a$, where $\hat{F}_a = \frac{K(6t+K)}{18t}$.

From propositions 2 and 3, we see that depending on the certification fee F, the symmetric or the asymmetric equilibrium can arise.

5.2 *Optimal Certification Policy*

In principle, the set of possible disclosure rules for the certifier can be large, e.g., it certifies products of quality θ (say) only, where $\theta \in [0, \bar{\theta}]$, it certifies all products whose qualities are higher or equal to θ and discloses their exact qualities, it certifies all products whose qualities are higher or equal to θ and discloses their qualities as qualities $\geq \theta$, it sets some noisy disclosure rule, etc. Following lemma 2, I can restrict my analysis to only one kind of disclosure rule.

Lemma 2. *To find the optimal certification policy for a for-profit certifier, it is sufficient to consider only the case where the certifier charges fee F_1 to certify quality θ_1 and a fee F_2 to certify quality θ_2, with $F_1 \leq F_2$ and $0 \leq \theta_1 \leq \theta_2 \leq \bar{\theta}$.*

Proof. Suppose the certifier certifies all products whose qualities are higher or equal to θ and discloses their qualities as qualities higher or equal to θ. Then none of the firms which opts for certification will produce qualities strictly higher than θ. This is due to the fact that, if a firm applies for certification and gets certification, through the certification result its quality is revealed as higher or equal to θ. Any quality that is strictly higher than θ is neither observed by its rival firm nor by consumers. For any positive ε as $c(\theta) < c(\theta + \varepsilon)$, the optimal quality choice for the firm seeking certification would be to produce quality θ. Thus the certifier can certify products of quality θ only. If the certifier certifies all products whose qualities are higher or equal to θ and discloses their exact qualities, then either one firm or both firms will opt for certification. If one firm opts for certification, it will produce products of quality $\bar{\theta}$, as producing quality $\bar{\theta}$ generates maximum surplus. So the certifier can certify products of quality $\bar{\theta}$ only. If both firms opt for certification, they can produce the same or different qualities. If they produce the same quality, they will choose $\bar{\theta}$, and so the certifier can just certify quality $\bar{\theta}$. If the firms produce different qualities, the certifier can certify only those two qualities for which the certifier can make maximum profit. In general, whatever disclosure rule the certifier announces, firms will choose at most two qualities. Therefore, among all possible disclosure rules, the for-profit certifier can certify two qualities for which the certifier can make maximum profit. □

Profit Certifier's Maximization Problem

Suppose the certifier announces a certification policy which states that it will certify qualities θ_1 and θ_2 with $0 \leq \theta_1 \leq \theta_2 \leq \bar{\theta}$, and to apply for certification, a firm has to pay fees F_1(for quality θ_1) and F_2 (for quality θ_2), with $F_1 \leq F_2$.

Given this certification policy, suppose that in equilibrium one firm (say firm 1) produces quality θ_1 and applies for certification by paying the fee F_1, whereas the other firm (firm 2) produces quality θ_2 and applies for certification by paying the fee F_2. Certification result R will reveal firm 1's quality to be θ_1 and that of firm 2 to be θ_2. Therefore, $\theta^e_{1,2} = \theta^e_1 = \theta_1$ and $\theta^e_{2,1} = \theta^e_2 = \theta_2$. Firm 1 and firm 2 set prices P^*_1 and P^*_2 respectively and make profits π^*_1 and π^*_2 respectively (see Appendix).

Deviations for firm 1: Given the strategies taken by firm 2 and the strategies taken by firm 1 in stage 2, P^*_1 is the optimal price that firm 1 can charge. Therefore, firm 1 has no incentive to deviate at the price setting stage.

Among all possible deviations for firm 1 in stage 2, the most profitable deviation is either to produce quality θ_2 and apply for certification or to produce quality 0 and not apply for certification. If firm 1 deviates by producing quality θ_2 and applies for certification by paying the fee F_2, through certification its quality will be revealed as θ_2. Firm 1 will set a price equal to $c(\theta_2) + t$, capture half of the market and make a profit of $\frac{t}{2} - F_2$. This deviation will not be profitable for firm 1 if $\pi^*_1 \geq \pi^D_1$, *i.e.* if

$$\frac{(3t + S(\theta_1) - S(\theta_2))^2}{18t} - F_1 \geq \frac{t}{2} - F_2. \tag{1}$$

If firm 1 deviates by producing quality 0 and not applying for certification, its quality is not observed. To make this deviation not profitable for firm 1, I assume that in such a situation firm 2 and all consumers will have the most pessimistic out of equilibrium beliefs about firm 1's quality, that is, they will all believe that firm 1's quality is 0 which implies $\theta^e_{1,2} = \theta^e_1 = 0$. Given this out of equilibrium belief, this deviation will not be profitable for firm 1 if π^*_1 is greater than or equal to its deviational profit (see Appendix), that is, if

$$F_1 \leq \frac{(S(\theta_1)-S(0))(6t+S(\theta_1)+S(0)-2S(\theta_2))}{18t} = f_1(\theta_1,\,\theta_2). \tag{2}$$

Deviations for firm 2: Similarly, it is not profitable for firm 2 to deviate only at the price setting stage. The most profitable deviations for firm 2 would be either to produce quality θ_1 and apply for certification or to produce quality 0 and not apply for certification. The first deviation will not be profitable if $\pi_2^* \geq \pi_2^D$, *i.e.* if

$$\frac{(3t+S(\theta_2)-S(\theta_1))^2}{18t} - F_2 \geq \frac{t}{2} - F_1, \tag{3}$$

and imposing similar out of equilibrium beliefs ($\theta_{2,1}^e = \theta_2^e = 0$) the second deviation will not be profitable if

$$F_2 \leq \frac{(S(\theta_2)-S(0))(6t+S(\theta_2)+S(0)-2S(\theta_1))}{18t} = f_2(\theta_1,\,\theta_2). \tag{4}$$

Given the certification policy, if conditions (1)-(4) are satisfied, one firm would opt for certification of quality θ_1 and the other would opt for certification of quality θ_2. In that case, the certifier earns a surplus of F_1+F_2, and it wants to maximize F_1+F_2 with respect to $\theta_1$and θ_2, where $\theta_1,\,\theta_2 \in [0,\,\bar{\theta}]$ and $\theta_1 \leq \theta_2$, such that conditions $(1)-(4)$ are satisfied. This is equivalent to maximizing $f_1(\theta_1,\,\theta_2)+f_2(\theta_1,\,\theta_2)$ with respect to θ_1 and θ_2, where $\theta_1,\,\theta_2 \in [0,\,\bar{\theta}]$ and $\theta_1 \leq \theta_2$, such that conditions $(1)-(4)$ are satisfied.

Using Kuhn Tucker conditions, I obtain the following solution for the certifier's maximization problem (see Appendix):

1. $\hat{\theta}_1 = 0$, $\hat{F}_1 = 0$, and $\hat{\theta}_2 = \bar{\theta}$, $\hat{F}_2 = \frac{K(6t+K)}{18t}$, for $t \leq \frac{K}{2}$,
2. $\hat{\theta}_1 = \hat{\theta}_2 = \bar{\theta}$, $\hat{F}_1 = \hat{F}_2 = \frac{K(6t-K)}{18t}$, for $t > \frac{K}{2}$.

In the first case where $\hat{\theta}_1 = 0, \hat{F}_1 = 0$ is equivalent to no certification. In this case, the certifier earns a surplus $\frac{K(6t+K)}{18t}$ and in the second case a surplus $\frac{K(6t-K)}{9t}$.

Note that for $t \leq \frac{K}{2}$, the firm which produces quality 0 will have a demand of $\frac{(3t-K)}{6t}$, which is positive for $t > \frac{K}{3}$. If $t \leq \frac{K}{3}$, the firm which produces quality $\bar{\theta}$ and opts for certification captures the entire market. In this case the certified firm can charge a price equal to $V(\bar{\theta}) - [V(0)-c(0)] - t$ and can capture the entire market. Hence the certifier can charge a different fee. If the certified firm deviates by not opting for certification, it will produce quality 0 and therefore will share the market equally with the other firm and will make a profit of $\frac{t}{2}$. The fee (F) that the certifier can charge to make this deviation not profitable for the certified firm satisfies the following:

$$K - t - F \geq \frac{t}{2} \Longleftrightarrow F \leq K - \frac{3t}{2}.$$

In this case the maximum fee ($\hat{F}$) the certifier can charge is equal to $K - \frac{3t}{2}$. Combining all these points, I obtain the following proposition.

Proposition 4. *In all equilibria the optimal certification policy for a for-profit certifier is to certify products of quality* $\bar{\theta}$ *only. The optimal certification fee* $\hat{F}$ *and market equilibrium is characterized by the following: there exists a unique pair of threshold values* ($t^* = \frac{K}{3}$, $t^{**} = \frac{K}{2}$) *of* t *such that,*

1) for $0 \leq t \leq t^*$, *there exists an equilibrium which is unique and asymmetric where* $\hat{F} = K - \frac{3t}{2}$, *one firm produces quality* $\bar{\theta}$ *and opts for certification, whereas the other produces quality 0 and does not opt for certification, and the certified firm captures the entire market,*

2) for $t^* < t \leq t^{**}$, *there exists an equilibrium which is unique and asymmetric where* $\hat{F} = \frac{K(6t+K)}{18t}$, *one firm produces quality* $\bar{\theta}$ *and opts for certification, whereas the other produces quality 0 and does not opt for certification, and both firms make positive profits,*

3) for $t > t^{**}$, *there exists an equilibrium which is unique and symmetric where* $\hat{F} = \frac{K(6t-K)}{18t}$, *both firms produce quality* $\bar{\theta}$ *and opt for certification, and both firms make equal profits.*

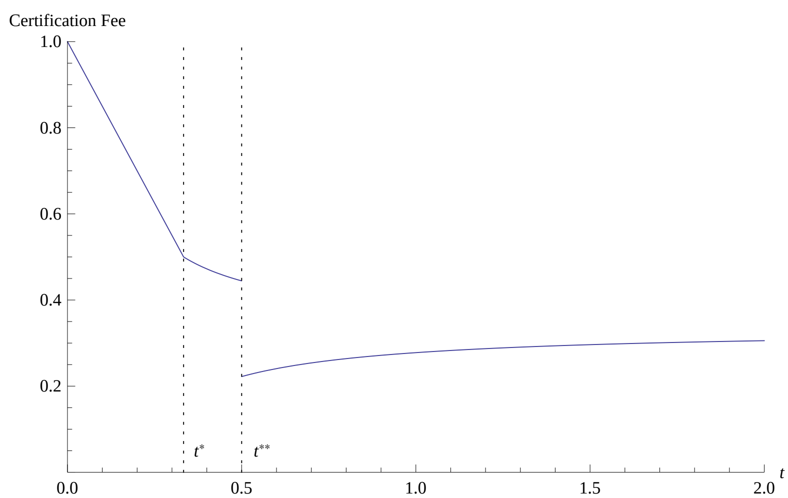

Figure 1: Graph of certification fee function vs t for $K = 1$. The vertical dotted lines in the left and the right are drawn at the points $t = t^*$ and $t = t^{**}$ respectively.

From proposition 4, I find that in all equilibria a for-profit certifier always certifies products of the highest quality only, but depending on the degree of horizontal differentiation, it charges different certification fees which lead to the asymmetric equilibrium or the symmetric equilibrium. When this horizontal differentiation is very low (when t is smaller than t^*), that is the competition between firms is very high, it charges such a high fee that only one firm produces the highest quality, opts for certification and captures the entire market, whereas the other firm produces the lowest quality and sells nothing. As the horizontal differentiation becomes larger than t^* but smaller or equal to t^{**}, the certifier charges a different fee but still high enough so that only one firm produces the highest quality and opts for certification. In this case, as competition between firms reduces, the non-certified firm which produces the lowest quality also gains some market power and sells to some consumers. This asymmetric equilibrium vanishes, as the horizontal differentiation becomes larger than t^{**}. Here as competition between firms becomes sufficiently low, both firms gain sufficient market power, therefore the certifier charges a much lower fee so that both firms produce the highest quality and opt for certification. Figures 1 and 2 show respectively how the certification fee charged by a for-profit certifier and its corresponding profit varies as the degree of horizontal differentiation between firms increases. The certification fee is discontinuous due to the change in equilibrium structure and is non-monotonic in t. As a consequence, the profit of the certifier is also non-monotone in t. One might think that as competition between firms becomes low, the certifier will make more profit which is not true here. The certifier makes more profit when the competition between firms is very intense and it does so by creating maximum vertical differentiation between the two firms.

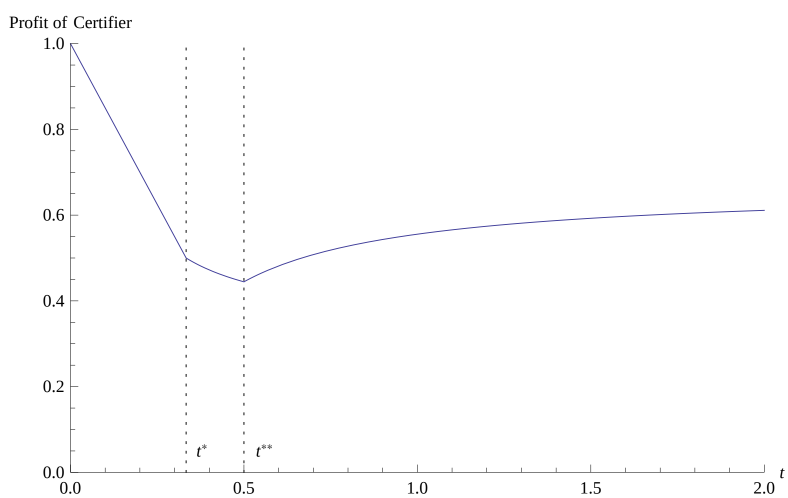

Figure 2: Graph of the certifier's profit function vs t for $K = 1$. The vertical dotted lines in the left and right are drawn at the points $t = t^*$ and $t = t^{**}$ respectively.

6 Welfare Analysis

A social planner wants to maximize social welfare. I measure social welfare by calculating the total surplus generated in each of the equilibria under a non-profit certifier and a for-profit certifier. As a non-profit certifier does not charge a certification fee, the total surplus in this case is just the sum of firms' total profits and consumer surplus. Under a for-profit certifier, the total surplus is the sum of industry profit (i.e., certifier's profit plus firms' total profits) and consumer surplus.

Under a non-profit certifier, each firm captures half of the market, sets the same price $c(\bar{\theta})+t$ and makes a profit of $\frac{t}{2}$. Total consumer surplus will be $2\int_0^{\frac{1}{2}}[V(\bar{\theta})-c(\bar{\theta})-t-tx^2]dx = S(\bar{\theta})-\frac{13t}{12}$.

Therefore under a non-profit certifier the total surplus is always $t+S(\bar{\theta})-\frac{13t}{12} = S(\bar{\theta})-\frac{t}{12}$, which is the maximum surplus that can be generated from the market.

t	Industry Profit	Consumer Surplus	Total Surplus
$0<t\leq t^*$	$K-t$	$S(0)+\frac{2t}{3}$	$S(\bar{\theta})-\frac{t}{3}$
$t^*<t\leq t^{**}$	$t+\frac{K^2}{9t}$	$\frac{K^2}{18t}+\frac{S(\bar{\theta})+S(0)}{2}-\frac{13t}{12}$	$\frac{K^2}{6t}+\frac{S(\bar{\theta})+S(0)}{2}-\frac{t}{12}$
$t>t^{**}$	t	$S(\bar{\theta})-\frac{13t}{12}$	$S(\bar{\theta})-\frac{t}{12}$

Table 1: The total surplus under a for-profit certifier

Table 1 gives the total surplus under a for-profit certifier for different values of t. Under a non-profit certifier, as each firm captures half of the market, the total transportation cost that is incurred by consumers is minimal. Both firms sell products of the highest quality which generates maximum surplus. Moreover, it can be checked easily that for $0<t\leq t^{**}$, the total surplus under a non-profit certifier is strictly higher than that under a for-profit certifier. For $0<t\leq t^*$, under a for-profit certifier as the certified firm captures the entire market, the total transportation cost incurred by the consumers is higher, which leads to the inefficiency. For $t^*<t\leq t^{**}$, the inefficiency arises for two reasons. Firstly, firms have unequal market shares and hence the total transportation cost incurred by consumers is higher. Secondly, as some consumers buy the lowest quality products, this yields lower surplus. For $t>\frac{K}{2}$, under both types of certifiers, only the symmetric equilibrium exists where both firms produce the highest quality and opt for certification. In this case, the total surplus remains the same under both types of certifier because under a for-profit certifier some surplus gets transferred from the firms to the certifier. Therefore, a social planner would weakly prefer to have a non-profit certifier rather than a for-profit certifier to operate in such markets.

7 Conclusion

In this paper I have analyzed a symmetric duopolistic market where each firm's choice concerning certain quality attributes such as environmental friendliness of its product is its own private information and have found that the degree of horizontal differentiation among firms plays a crucial role in a for-profit certifier's optimal certification policy. Under a for-profit certifier, there exists a threshold value of the degree of horizontal differentiation below which the certifier charges such a high fee that only one of the firms produces the highest quality and opts for certification, whereas the other firm produces the lowest quality and does not opt for certification. Moreover, when the horizontal differentiation is sufficiently small, the certified firm captures the entire market. Basically when competition between the firms is very high, in order to make maximum profit, a for-profit certifier, by charging a very high, fee creates maximum vertical differentiation between firms. Above this threshold value, that is, when the competition between firms becomes low, both firms gain sufficient monopoly power over their respective market shares. This compels the certifier to reduce its fee significantly and both firms produce the highest quality and opt for certification. Under a non-profit certifier, this asymmetric equilibrium vanishes. In this case, only the symmetric equilibrium exists where both firms produce the highest quality and opt for certification, which is also the most efficient. The asymmetric equilibrium arising under a for-profit certifier makes the market inefficient, and therefore, it is socially optimal to have a non-profit certifier rather than a for-profit certifier in such a market. This could be viewed as one of the possible reasons that we find mostly non-profit certifiers operating in such markets.

The for-profit certifier always certifies the highest quality because of the assumption that surplus generated by quality is strictly increasing with quality. If $S(\theta)$ is non-monotonic, it will certify that quality level which generates maximum surplus. I assume that the function $S(\theta)$ is strictly increasing in θ in line with the literature, and under this assumption the for-profit certifier always certifies the highest quality only, which makes it easier to compare with a non-profit certifier case. Under both types of certifier, only the highest quality products are certified. It is only through the certification fee that the for-profit certifier can create an asymmetry in the market.

Future research could introduce competition between for-profit certifiers. It would be interesting to see if different certifiers certify different quality levels, but it seems very likely that all the for-profit certifiers will certify the highest quality only, but due to Bertrand competition the certification fee will be zero, which is similar to one of the results in Lizzeri (1999). Another possible future development of this work could be to introduce heterogeneity among consumers in terms of their valuations for qualities, and study its effects.

Appendix

Proof of Proposition 1: Both firms produce $\bar{\theta}$ and opt for certification. Let a consumer located at point $\hat{d}$ be indifferent between buying from firm 1 and firm 2. Then,

$$V(\bar{\theta}) - P_1 - t\hat{d}^2 = V(\bar{\theta}) - P_2 - t(1-\hat{d})^2 \Longleftrightarrow \hat{d} = \frac{P_2 - P_1 + t}{2t}.$$

The demand faced by firm 1 is given by $D_1 = \frac{P_2-P_1+t}{2t}$ and that of firm 2 is $D_2 = 1-\hat{d} = \frac{P_1-P_2+t}{2t}$. Profit functions of firms 1 and 2 are $\pi_1 = [P_1 - c(\bar{\theta})][\frac{P_2-P_1+t}{2t}]$ and $\pi_2 = [P_2 - c(\bar{\theta})][\frac{P_1-P_2+t}{2t}]$ respectively. Therefore, firm 1 will maximize π_1 with respect to P_1 and firm 2 will maximize π_2 with respect to P_2. The two first order conditions and the symmetry yield $P_1^* = P_2^* = c(\bar{\theta}) + t$. Each of the firms faces a demand equal to $\frac{1}{2}$ and earns a profit of $\frac{t}{2}$ each.

Most profitable deviation: Suppose either of the firms (say firm 1) deviates by producing quality 0 and not applying for certification. Imposing $\theta_{1,r}^e = 0$ and $\theta_1^e = 0$, the indifferent consumer is given by $\hat{d} = \frac{P_2 - P_1^D + t - V(\bar{\theta}) + V(0)}{2t}$. Therefore, the demand faced by firm 1 is $D_1 = \frac{P_2 - P_1^D + t - V(\bar{\theta}) + V(0)}{2t}$ and that of firm 2 is $D_2 = 1 - \hat{d} = \frac{P_1^D - P_2 + t + V(\bar{\theta}) - V(0)}{2t}$. The profit functions of firms 1 and 2 will be $\pi_1^D = [P_1^D - c(0)][\frac{P_2 - P_1^D + t - V(\bar{\theta}) + V(0)}{2t}]$ and $\pi_2 = [P_2 - c(\bar{\theta})][\frac{P_1^D - P_2 + t + V(\bar{\theta}) - V(0)}{2t}]$ respectively. Solving for P_1^D and P_2 from the two first order conditions I obtain $P_1^D = \frac{2c(0) + c(\bar{\theta}) + 3t + V(0) - V(\bar{\theta})}{3}$ and $P_2 = \frac{2c(\bar{\theta}) + c(0) + 3t - V(0) + V(\bar{\theta})}{3}$. Substituting P_1^D and P_2 in D_1 and D_2, I obtain $D_1 = \frac{(3t-K)}{6t}$ and $D_2 = \frac{(3t+K)}{6t}$. The deviational profit for firm 1 will be $\pi_1^D = \frac{(3t-K)^2}{18t}$. Rest of the proof is given in section 4.

Proof of Proposition 2: Both firms produce θ and opt for certification. Let a consumer located at point $\hat{d}$ be indifferent between buying from firm 1 and firm 2. Then,

$$V(\theta) - P_1 - t\hat{d}^2 = V(\theta) - P_2 - t(1-\hat{d})^2 \Longleftrightarrow \hat{d} = \frac{P_2 - P_1 + t}{2t}.$$

The demand faced by firm 1 is given by $D_1 = \frac{P_2-P_1+t}{2t}$ and that of firm 2 is $D_2 = 1-\hat{d} = \frac{P_1-P_2+t}{2t}$. The profit functions of firms 1 and 2 are $\pi_1 = [P_1 - c(\theta)][\frac{P_2-P_1+t}{2t}] - F_s$ and $\pi_2 = [P_2 - c(\theta)][\frac{P_1-P_2+t}{2t}] - F_s$. Maximizing π_1 and π_2 with respect to P_1 and P_2 and imposing symmetry yields $P_1^* = P_2^* = c(\theta) + t$. Each of the firms faces a demand equal to $\frac{1}{2}$ and earns a profit of $\frac{t}{2} - F_s$ each.

Most profitable deviation: Suppose firm 1 deviates by producing quality 0 and not applying for certification. Imposing $\theta^e_{1,r} = 0$ and $\theta^e_1 = 0$, the indifferent consumer is given by $\hat{d} = \frac{P_2 - P_1^D + t - V(\theta) + V(0)}{2t}$. Therefore, the demand faced by firm 1 is $D_1 = \frac{P_2 - P_1^D + t - V(\theta) + V(0)}{2t}$ and that of firm 2 is $D_2 = 1 - \hat{d} = \frac{P_1^D - P_2 + t + V(\theta) - V(0)}{2t}$. The profit functions of firms 1 and 2 will be $\pi_1^D = [P_1^D - c(0)][\frac{P_2 - P_1^D + t - V(\theta) + V(0)}{2t}]$ and $\pi_2 = [P_2 - c(\theta)][\frac{P_1^D - P_2 + t + V(\theta) - V(0)}{2t}] - F_s$ respectively. Solving for P_1^D and P_2 from the two first order conditions, I obtain $P_1^D = \frac{2c(0) + c(\theta) + 3t + V(0) - V(\theta)}{3}$ and $P_2 = \frac{2c(\theta) + c(0) + 3t - V(0) + V(\theta)}{3}$. The deviational profit for firm 1 will be $\pi_1^D = \frac{(3t + [V(0) - c(0)] - [V(\theta) - c(\theta)])^2}{18t}$. This deviation will not be profitable for firm 1 if

$$\frac{t}{2} - F_s \geq \frac{(3t + [V(0) - c(0)] - [V(\theta) - c(\theta)])^2}{18t} \iff F_s \leq \frac{t}{2} - \frac{(3t + [V(0) - c(0)] - [V(\theta) - c(\theta)])^2}{18t}$$

$$\iff F_s \leq \frac{([V(\theta) - c(\theta)] - [V(0) - c(0)])(6t - ([V(\theta) - c(\theta)] - [V(0) - c(0)]))}{18t} = \frac{w(\theta)(6t - w(\theta))}{18t}.$$

If F_s satisfies above inequality, no firm has an incentive to deviate, which completes the proof.

Proof of Proposition 3: Suppose one firm (say firm 2) produces quality θ and applies for certification and the other (firm 1) does not apply for certification. As firm 1 does not opt for certification, its quality is not observed by firm 2 and by consumers. Therefore, firm 1's best possible quality choice would be to produce quality 0. Firm 1 and firm 2 set prices P_1 and P_2 respectively. Let a consumer located at point $\hat{d}$ be indifferent between buying from firm 1 and firm 2. Then,

$$V(0) - P_1 - t\hat{d}^2 = V(\theta) - P_2 - t(1 - \hat{d})^2 \iff \hat{d} = \frac{P_2 - P_1 + t - V(\theta) + V(0)}{2t}.$$

The demand faced by firm 1 is given by $D_1 = \frac{P_2 - P_1 + t - V(\theta) + V(0)}{2t}$ and that of firm 2 is $D_2 = 1 - \hat{d} = \frac{P_2 - P_1 + t + V(\theta) - V(0)}{2t}$. The profit functions of firms 1 and 2 are $\pi_1 = [P_1 - c(0)][\frac{P_2 - P_1 + t - V(\theta) + V(0)}{2t}]$ and $\pi_2 = [P_2 - c(\theta)][\frac{P_2 - P_1 + t + V(\theta) - V(0)}{2t}] - F_a$ respectively. Maximizing π_1 and π_2 with respect to P_1 and P_2 respectively, I obtain $P_1^* = \frac{2c(0) + c(\theta) + 3t + V(0) - V(\theta)}{3}$ and $P_2^* = \frac{2c(\theta) + c(0) + 3t - V(0) + V(\theta)}{3}$. Hence, the profits will be $\pi_1^* = \frac{(3t + [V(0) - c(0)] - [V(\theta) - c(\theta)])^2}{18t}$ and $\pi_2^* = \frac{(3t + [V(\theta) - c(\theta)] - [V(0) - c(0)])^2}{18t} - F_a$.

Most profitable deviation for the certified firm: Suppose firm 2 deviates by producing quality 0 and not applying for certification. Then both the firms produce quality 0 and do not apply for certification. Imposing the belief of each firm regarding the quality choice of its rival and that of consumers, the deviational price will be $P_2^D = c(0) + t$, each of the firms will face a demand equal to $\frac{1}{2}$, and $\pi_2^D = \frac{t}{2}$. To have this deviation not profitable for firm 2, we must have

$$\frac{(3t + [V(\theta) - c(\theta)] - [V(0) - c(0)])^2}{18t} - F_a \geq \frac{t}{2}$$

$$\iff F_a \leq \frac{([V(\theta) - c(\theta)] - [V(0) - c(0)])(6t + [V(\theta) - c(\theta)] - [V(0) - c(0)])}{18t}. \tag{5}$$

Most profitable deviation for the non-certified firm: Suppose firm 1 deviates by producing quality θ and applying for certification. In this case, both the firms produce quality θ and apply for certification. So each of the firms will charge prices equal to $c(\theta) + t$, each facing a demand equal to $\frac{1}{2}$, and will earn a profit of $\frac{t}{2} - F_a$. This deviation will not be profitable for firm 1 if

$$\frac{(3t + [V(0) - c(0)] - [V(\theta) - c(\theta)])^2}{18t} \geq \frac{t}{2} - F_a$$

$$\iff F_a \geq \frac{([V(\theta) - c(\theta)] - [V(0) - c(0)])(6t - ([V(\theta) - c(\theta)] - [V(0) - c(0)]))}{18t}. \tag{6}$$

Combining conditions (5) & (6), I obtain

$$\frac{([V(\theta) - c(\theta)] - [V(0) - c(0)])(6t - ([V(\theta) - c(\theta)] - [V(0) - c(0)]))}{18t} \leq F_a$$

$$\leq \frac{([V(\theta) - c(\theta)] - [V(0) - c(0)])(6t + [V(\theta) - c(\theta)] - [V(0) - c(0)])}{18t}.$$

If F_a satisfies the above inequalities, neither firm has an incentive to deviate, which completes the proof.

Maximization problem for the for-profit certifier: The certifier announces a certification policy which states that it will certify qualities θ_1 and θ_2 with $0 \leq \theta_1 \leq \theta_2 \leq \bar{\theta}$, and to apply for certification, a firm has to pay fees F_1(for quality θ_1) and F_2 (for quality θ_2), with $F_1 \leq F_2$. Given the certification policy, suppose one firm (say firm 1) produces quality θ_1 and applies for certification by paying the fee F_1, whereas the other firm (firm 2) produces quality θ_2 and applies for certification by paying the fee F_2. Let a consumer located at point $\hat{d}$ be indifferent between buying from firm 1 and firm 2. Then,

$$V(\theta_1) - P_1 - t\hat{d}^2 = V(\theta_2) - P_2 - t(1-\hat{d})^2 \Longleftrightarrow \hat{d} = \frac{P_2 - P_1 + t - V(\theta_2) + V(\theta_1)}{2t}.$$

The demands of firm 1 and 2 are given by $D_1 = \frac{P_2 - P_1 + t - V(\theta_2) + V(\theta_1)}{2t}$ and $D_2 = \frac{P_1 - P_2 + t + V(\theta_2) - V(\theta_1)}{2t}$ respectively. Therefore, their profits will be $\pi_1 = [P_1 - c(\theta_1)][\frac{P_2 - P_1 + t - V(\theta_2) + V(\theta_1)}{2t}] - F_1$ and $\pi_2 = [P_2 - c(\theta_2)][\frac{P_1 - P_2 + t + V(\theta_2) - V(\theta_1)}{2t}] - F_2$ respectively. Maximizing π_1 and π_2 with respect to P_1 and P_2 respectively, I obtain $P_1^* = \frac{2c(\theta_1) + c(\theta_2) + 3t + V(\theta_1) - V(\theta_2)}{3}$ and $P_2^* = \frac{2c(\theta_2) + c(\theta_1) + 3t - V(\theta_1) + V(\theta_2)}{3}$. Hence the profits are $\pi_1^* = \frac{(3t + [V(\theta_1) - c(\theta_1)] - [V(\theta_2) - c(\theta_2)])^2}{18t} - F_1$ and $\pi_2^* = \frac{(3t + [V(\theta_2) - c(\theta_2)] - [V(\theta_1) - c(\theta_1)])^2}{18t} - F_2$.

Most profitable deviations for firm 1: Suppose firm 1 deviates by producing quality θ_2 and applying for certification. In that case, the profits of firm 1 and 2 will be $\pi_1^D = [P_1^D - c(\theta_2)][\frac{P_2 - P_1^D + t}{2t}] - F_2$ and $\pi_2 = [P_2 - c(\theta_2)][\frac{P_1^D - P_2 + t}{2t}] - F_2$. Firm 1 will maximize π_1^D with respect to P_1^D and firm 2 will maximize π_2 with respect to P_2. The two first order conditions and the symmetry yield $P_1^D = P_2 = c(\theta_2) + t$. Each of the firms faces a demand equal to $\frac{1}{2}$ and earns a profit of $\frac{t}{2} - F_2$ each. This deviation will not be profitable for firm 1 if

$$\frac{(3t + [V(\theta_1) - c(\theta_1)] - [V(\theta_2) - c(\theta_2)])^2}{18t} - F_1 \geq \frac{t}{2} - F_2$$

$$\Longleftrightarrow \frac{(3t + S(\theta_1) - S(\theta_2))^2}{18t} - F_1 \geq \frac{t}{2} - F_2. \tag{7}$$

Suppose firm 1 deviates by producing quality 0 and not applying for certification. Imposing $\theta_{1,2}^e = 0$ and $\theta_1^e = 0$, the profit functions of firms 1 and 2 are $\pi_1^D = [P_1 - c(0)][\frac{P_2 - P_1^D + t - V(\theta_2) + V(0)}{2t}]$ and $\pi_2 = [P_2 - c(\theta_2)][\frac{P_1^D - P_2 + t + V(\theta_2) - V(0)}{2t}] - F_2$. Maximizing π_1^D and π_2 with respect to P_1^D and P_2 respectively, I obtain $P_1^D = \frac{2c(0) + c(\theta_2) + 3t + V(0) - V(\theta_2)}{3}$ and $P_2 = \frac{2c(\theta_2) + c(0) + 3t - V(0) + V(\theta_2)}{3}$. The deviational profit for firm 1 will be $\pi_1^D = \frac{(3t + [V(0) - c(0)] - [V(\theta_2) - c(\theta_2)])^2}{18t}$. This deviation not profitable for firm 1, we must have

$$\frac{(3t + [V(\theta_1) - c(\theta_1)] - [V(\theta_2) - c(\theta_2)])^2}{18t} - F_1 \geq \frac{(3t + [V(0) - c(0)] - [V(\theta_2) - c(\theta_2)])^2}{18t}$$

$$\Longleftrightarrow F_1 \leq \frac{(3t + [V(\theta_1) - c(\theta_1)] - [V(\theta_2) - c(\theta_2)])^2}{18t} - \frac{(3t + [V(0) - c(0)] - [V(\theta_2) - c(\theta_2)])^2}{18t}$$

$$\Longleftrightarrow F_1 \leq \frac{([V(\theta_1) - c(\theta_1)] - [V(0) - c(0)])(6t + [V(\theta_1) - c(\theta_1)] + [V(0) - c(0)] - 2[V(\theta_2) - c(\theta_2)])}{18t}$$

$$\Longleftrightarrow F_1 \leq \frac{(S(\theta_1)-S(0))(6t+S(\theta_1)+S(0)-2S(\theta_2))}{18t} = f_1(\theta_1,\, \theta_2). \tag{8}$$

Most profitable deviations for firm 2: Similarly, it will not be profitable for firm 2 to deviate by producing quality θ_1 and to apply for certification if

$$\frac{(3t+S(\theta_2)-S(\theta_1))^2}{18t} - F_2 \geq \frac{t}{2} - F_1. \tag{9}$$

Imposing similar out of equilibrium beliefs ($\theta^e_{2,1} = \theta^e_2 = 0$), the deviation to produce quality 0 and not apply for certification will not be profitable for firm 2 if

$$F_2 \leq \frac{(S(\theta_2)-S(0))(6t+S(\theta_2)+S(0)-2S(\theta_1))}{18t} = f_2(\theta_1,\, \theta_2). \tag{10}$$

The certifier wants to

$$\underset{\theta_1,\,\theta_2}{maximize}\,(f_1(\theta_1,\, \theta_2)+f_2(\theta_1,\, \theta_2))$$

subject to the following conditions

$$\frac{(3t+S(\theta_1)-S(\theta_2))^2}{18t} - f_1(\theta_1,\, \theta_2) - \frac{t}{2} + f_2(\theta_1,\, \theta_2) \geq 0,$$

$$\frac{(3t+S(\theta_2)-S(\theta_1))^2}{18t} - f_2(\theta_1,\, \theta_2) - \frac{t}{2} + f_1(\theta_1,\, \theta_2) \geq 0,$$

$$f_2(\theta_1,\, \theta_2) - f_1(\theta_1,\, \theta_2) \geq 0,$$

$$0 \leq \theta_1,\, \theta_2 \leq \bar{\theta},$$

$$\theta_2 - \theta_1 \geq 0.$$

Let us call the above maximization problem $M1$. Now maximizing $f_1(\theta_1,\, \theta_2)+f_2(\theta_1,\, \theta_2)$ with respect to θ_1 and θ_2 subject to the above five constraints is equivalent to maximizing $18t(f_1(\theta_1,\, \theta_2)+f_2(\theta_1,\, \theta_2))$ with respect to θ_1 and θ_2 subject to the above five constraints. Now consider the following maximization problem $M2$:

$$\underset{\theta_1,\,\theta_2}{maximize}\,18t(f_1(\theta_1,\, \theta_2)+f_2(\theta_1,\, \theta_2))$$

subject to $\theta_1 \geq 0$, $\theta_1 \leq \bar{\theta}$, $\theta_2 \leq \bar{\theta}$, $\theta_1 \leq \theta_2$.

Note that, due to having fewer constraints, the maximum of $M2$ will be less than or equal to the maximum of

$M1$.

Let us define the following:

$x(\theta_1) = [V(\theta_1) - c(\theta_1)] - [V(0) - c(0)]$, and

$y(\theta_2) = [V(\theta_2) - c(\theta_2)] - [V(0) - c(0)]$.

Clearly $x(\theta_1)$ is increasing in θ_1 and $y(\theta_2)$ is increasing in θ_2, and $x(\theta_1), y(\theta_2) \in [0, K]$. I denote $x(\theta_1)$ as x and $y(\theta_2)$ as y. Therefore $M2$ is equivalent to the following maximization problem $M3$:

$$\underset{x,y}{maximize}\, x(6t + x - 2y) + y(6t + y - 2x)$$

subject to $x \geq 0$, $x \leq K$, $y \leq K$, $x \leq y$.

I solve $M3$ using Kuhn-Tucker conditions. The Lagrangian is

$L(x, y, \mu_1, \mu_2, \mu_3, \mu_4) = x(6t + x - 2y) + y(6t + y - 2x) + \mu_1 x + \mu_2(K - x) + \mu_3(K - y) + \mu_4(y - x)$,

which gives the following optimality conditions:

$6t - 4y + 2x + \mu_1 - \mu_2 - \mu_4 = 0$, $6t - 4x + 2y - \mu_3 + \mu_4 = 0$, $\mu_1 x = 0$,

$\mu_2(K - x) = 0$, $\mu_3(K - y) = 0$, $\mu_4(y - x) = 0$, $x \geq 0$, $K - x \geq 0$,

$K - y \geq 0$, $y - x \geq 0$, $\mu_1, \mu_2, \mu_3, \mu_4 \geq 0$.

Since there are four complementarity conditions, I need to consider sixteen cases:

1. $\mu_1, \mu_2, \mu_3, \mu_4 = 0$: gives $x = 3t$, $y = 3t$, provided $K \geq 3t$ and the maximum value is $18t^2$.

2. $\mu_1 \neq 0 \Rightarrow x = 0$, $\mu_2, \mu_3, \mu_4 = 0$: gives $y = -3t$, not feasible.

3. $\mu_1 \neq 0 \Rightarrow x = 0$, $\mu_2 \neq 0 \Rightarrow x = K$, not possible. So I rule out all four cases where $\mu_1, \mu_2 \neq 0$.

4. $\mu_1 \neq 0 \Rightarrow x = 0$, $\mu_2 = 0$, $\mu_3 \neq 0 \Rightarrow y = K$, $\mu_4 \neq 0 \Rightarrow y = x$, not possible.

5. $\mu_1 \neq 0 \Rightarrow x = 0$, $\mu_2 = 0$, $\mu_3 \neq 0 \Rightarrow y = K$, $\mu_4 = 0$: gives $\mu_1 = 4K - 6t > 0 \Rightarrow K > \frac{3t}{2}$, $\mu_3 = 6t + 2K > 0$. The maximum value is $K(6t + K) = 6tK + K^2$.

6. $\mu_1 \neq 0 \Rightarrow x = 0$, $\mu_2 = 0$, $\mu_3 = 0$, $\mu_4 \neq 0 \Rightarrow y = x = 0$: gives $\mu_1 = -12t$ and $\mu_4 = -6t$, not feasible.

7. $\mu_1 = 0$, $\mu_2 \neq 0 \Rightarrow x = K$, $\mu_3, \mu_4 = 0$: gives $y = 2K - 3t \geq 0 \Rightarrow K \geq \frac{3t}{2}$, $\mu_2 = 18t - 6k > 0 \Rightarrow K < 3t$, $y - x \geq 0 \Rightarrow K \geq 3t$, not possible as the last two conditions cannot hold simultaneously.

8. $\mu_1, \mu_2 = 0$, $\mu_3 \neq 0 \Rightarrow y = K$, $\mu_4 = 0$: gives $x = 2K - 3t \geq 0 \Rightarrow K \geq \frac{3t}{2}$, $\mu_3 = 18t - 6K > 0 \Rightarrow K < 3t$, $y - x \geq 0 \Rightarrow K \leq 3t$. Combining together I obtain, for $\frac{3t}{2} \leq K < 3t$, $x = 2K - 3t$, $y = K$, and the maximum value is $18Kt - 9t^2 - 3K^2$.

9. $\mu_1, \mu_2, \mu_3 = 0, \mu_4 \neq 0 \Rightarrow y = x :$ gives $x = y = 3t$, but $\mu_4 = 0$, which contradicts $\mu_4 \neq 0$. So this is not possible.

10. $\mu_1 = 0, \mu_2 \neq 0 \Rightarrow x = K, \mu_3 \neq 0 \Rightarrow y = K, \mu_4 = 0 :$ gives $\mu_2 = \mu_3 = 6t - 2K > 0 \Rightarrow K < 3t$. The maximum value is $2K(6t - K) = 12Kt - 2K^2$.

11. $\mu_1 = 0, \mu_2 \neq 0 \Rightarrow x = K, \mu_3 = 0, \mu_4 \neq 0 \Rightarrow y = x = K :$ gives $\mu_2 = 6t - 2K > 0 \Rightarrow K < 3t$, $\mu_3 = 2K - 6t > 0 \Rightarrow K > 3t$, not possible simultaneously.

12. $\mu_1 = 0, \mu_2 \neq 0 \Rightarrow x = K, \mu_3 \neq 0 \Rightarrow y = K, \mu_4 \neq 0 \Rightarrow y = x = K :$ gives $\mu_2 + \mu_3 = 12t - 4K > 0 \Rightarrow K < 3t$ and $\mu_4 = 6t - 2K - \mu_2$.There are many possible values of μ_2, μ_3 and μ_4 which satisfy the two conditions, one of which is $\mu_2 = 3t - K$, $\mu_3 = 9t - 3K$, $\mu_4 = 3t - K$. The maximum value is $2K(6t - K) = 12Kt - 2K^2$.

13. $\mu_1, \mu_2 = 0, \mu_3 \neq 0 \Rightarrow y = K, \mu_4 \neq 0 \Rightarrow y = x = K :$ gives $\mu_4 = 6t - 2K > 0 \Rightarrow K < 3t$, $\mu_3 = 12t - 4K > 0 \Rightarrow K < 3t$. The maximum value is $2K(6t - K) = 12Kt - 2K^2$.

Combining all the above, I obtain

for $K \geq 3t$, $x = y = 3t$, maximum value $18t^2$,

for $K > \frac{3t}{2}$, $x = 0$, $y = K$, maximum value $6tK + K^2$,

for $\frac{3t}{2} \leq K < 3t$, $x = 2K - 3t$, $y = K$, maximum value $18Kt - 9t^2 - 3K^2$,

for $K < 3t$, $x = y = K$, maximum value $12Kt - 2K^2$.

Now it is easy to check that $6tK + K^2 > 18Kt - 9t^2 - 3K^2$ and $12Kt - 2K^2 > 18Kt - 9t^2 - 3K^2$.

As $6tK + K^2 > 12Kt - 2K^2 \iff K > 2t$,

for $K < 2t$, $x = y = K$, is optimal.

And as $6tK + K^2 > 18t^2 \iff K > 3t(\sqrt{3} - 1)$, which is smaller than $3t$,

for $K \geq 2t$,$x = 0$, $y = K$, is optimal.

Therefore the optimal solution of the $M3$ is:

for $K < 2t$, $x = y = K$, the maximum value is $12Kt - 2K^2$,

for $K \geq 2t$, $x = 0$, $y = K$, the maximum value is $6tK + K^2$.

Therefore the optimal solution of $M2$ is :

for $K < 2t$, $\hat{\theta}_1 = \hat{\theta}_2 = \bar{\theta}$, the maximum value is $12Kt - 2K^2$,

for $K \geq 2t$, $\hat{\theta}_1 = 0$, $\hat{\theta}_2 = \bar{\theta}$, the maximum value is $6tK + K^2$.

It can be verified that the solution for $M2$ also satisfies all the constraints for $M1$. Therefore the optimal solution of $M1$ is

for $t > \frac{K}{2}$, $\hat{\theta}_1 = \hat{\theta}_2 = \bar{\theta}$, $f_1\widehat{(\theta_1, \theta_2)} = f_2\widehat{(\theta_1, \theta_2)} = \frac{6Kt-K^2}{18t}$, the maximum value is $\frac{12Kt-2K^2}{18t}$,
for $t \leq \frac{K}{2}$, $\hat{\theta}_1 = 0$, $\hat{\theta}_2 = \bar{\theta}$, $f_1\widehat{(\theta_1, \theta_2)} = 0$, $f_2\widehat{(\theta_1, \theta_2)} = \frac{6tK+K^2}{18t}$, the maximum value is $\frac{6tK+K^2}{18t}$.

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