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# Firms' Incentives to Disclose Information about Product Quality: The Case of Multi-Attribute Products with Heterogeneous Consumers*

by

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September 2002

*We wish to thank Dan Ackerberg, Harold Demsetz, Ginger Zhe Jin, John Riley, Phillip Leslie, Robert Porter, Kenneth Sokoloff, participants of the IO Seminar at UCLA, and participants of the 2002 North American Econometric Society Summer Meeting and 2002 Annual Conference of the European Association for Research in Industry Economics for comments on a preliminary version of this paper. All errors are ours. This research was funded by a grant from the National Institute for Child Health and Human Development (R01 HD035382). The authors are solely responsible for the contents of the paper.

## Abstract

In this paper, we examine the incentives for firms to voluntarily disclose otherwise private information about quality attributes of differentiated products when those products have multiple attributes and consumers are heterogeneous in their tastes over these attributes. In particular, we focus on whether the so-called "unraveling result"—in equilibrium, firms fully disclose the quality of their products voluntarily when disclosure costs are zero—holds when disclosure of quality information adds vertical differentiation into a product world with existing horizontal differentiation. We show that there exist certain configurations of consumer multidimensional preferences under which firms, even with high-quality products, may not have incentive to disclose. This failure to disclose voluntarily will arise when disclosure results in more elastic demand for products and hence triggers more intense price competition among firms, leading to lower prices for all products. The escalation of competition can make all firms worse off and lead firms to not disclose the quality of their products, even with zero disclosure costs. As a result, the equilibrium in which quality disclosure is voluntary may diverge from that in which quality disclosure is mandatory.



**JEL classifications:** L15 (Information and Product Quality);
L5 (Regulation and Industrial Policy)

**Keywords:** Quality Disclosure; Multiple Attributes; Consumer Heterogeneity



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## 1. Introduction

In independent studies, Grossman (1981) and Milgrom (1981) consider the decisions of firms to voluntarily supply information about the (unobserved) quality of their products to less than perfectly informed consumers. The privately-informed firms are assumed to have access to mechanisms with which they can costlessly and credibly disclose the quality of their products. These firms then decide whether to voluntarily disclose the quality of their products to consumers.

In what has become known as the "unraveling result," Grossman and Milgrom establish that firms will end up voluntarily disclosing the quality of their products and those undisclosed are (correctly) inferred by consumers to have products with the worst quality. The logic of their finding is as follows. If no firm discloses the quality of its product, then consumers believe the highest-quality product to be no different from the lowest-quality one. As a result, firms producing products with the highest quality have a clear incentive to disclose their quality, since they will then be able to charge higher prices and achieve higher profits. Firms with the next highest quality products similarly have the same incentive to differentiate themselves from the remaining firms (with lower quality products) and, as a result, will find it in their interests to disclose the quality of their products, charge higher prices and realize higher profits.

This unraveling of the private information held by firms continues, so long as the benefits of disclosure outweigh the costs. If the costs of disclosing credible information about product quality are truly zero, then, in the limit, full disclosure by all firms prevails in a market, i.e., the situation in which firms hold private information about product quality "unravels." As a result, it follows that there is little scope for firms to act strategically with respect to product quality disclosure decisions. High-quality firms, by distinguishing themselves from lower-

quality ones, can always gain from revealing their true quality level by charging a premium for the quality difference. Only those with the lowest quality will choose no revelation, because they will certainly lose from not being viewed as with average quality.

As has been noted elsewhere,[1] the unraveling result of Grossman and Milgrom has rather startling implications for regulatory policy for products and services with (quality) attributes that are difficult for consumers to determine prior to their purchase. In particular, it would appear to imply that mandatory requirements that sellers disclose the quality of their products are, at best, redundant, since the presence of competitors would appear to provide sufficient incentives for firms to voluntarily disclose sufficient information about product quality to consumers so that the latter group is fully informed about the products and services available in a particular market. More precisely, the unraveling result suggests that the only "intervention" needed by consumers is ensuring the availability of low-cost and credible disclosure mechanisms for sellers to use.

A number of subsequent studies have examined seller incentives for voluntary disclosure of product quality for refinements of the Grossman and Milgrom models and their unraveling result.[2] For example, studies have extended their models to allow for certain types of disclosure costs (Jovanovic, 1982; Verrecchia, 1983; Dye, 1986), costs of information acquisition by sellers (Matthews and Postlewaite, 1985; Farrell, 1986, Shavell, 1994), and alternative market structures (Jin, 2000). For most of these extensions, the basic conclusion that voluntary disclosure by sellers about product quality will occur in equilibrium continues to hold, so long as disclosure costs are zero. To our knowledge, there are only two lines of research that challenge

[1] See Farrell (1986) and Fishman and Hagerty (1999) for surveys of this literature and discussions of the implications of the unraveling result of Grossman and Milgrom.

[2] For a review of the information disclosure literature, see Fishman and Hagerty (1997)

the robustness of the "unraveling" result and its policy implications. Fishman and Hagerty (1999) argue that voluntary disclosure may not occur when a subset of consumers in the market are "unsophisticated" and do not understand the information disclosed by sellers about the quality of their products.[3] Alternatively, Farrell (1986) notes that voluntary disclosure may not occur in markets where the sellers, themselves, do not have complete information about the quality of their own products. In both of these cases, the failure to obtain voluntary disclosure from sellers hinges on a form of costs associated with disclosure.

In this paper, we develop a model with consumers' heterogeneity over multi-attribute products to suggest alternative explanations for the non-robustness of the unraveling result, even when there are no costs associated with disclosure. In particular, we examine the incentives for voluntary disclosure by sellers for products that have multiple attributes which different consumers value differently. The work of Becker (1965), Lancaster (1966), Muth (1966), Rosen (1974), and Gorman (1980) emphasize that all goods and services are best viewed as bundles of characteristics, including "quality," and that tastes are plausibly heterogeneous over these attributes and, thus, over the bundles. These two features—products-as-bundles-of-characteristics and consumer-heterogeneity—are at the core of the literature on hedonic pricing and markets for differentiated products.

Following the literature on product differentiation,[4] we consider a model in which products are both horizontally and vertically differentiated and where the vertical attribute is not observable by consumers.[5] In this context, we show that sellers whose products are high in quality

[3] Stivers (2001) offers a similar model in which voluntary disclosure may not occur.

[4] See Chapter 7 of Tirole (1994) for a summary of this literature.

[5] As discussed below, the results we derive do not require this particular configuration of product differentiation. Products may consist of attributes with any mix of horizontally- and vertically-differentiated attributes, including goods that consist of attributes that are exclusively of one type or the other. What is crucial for our model is that consumers have heterogeneous preferences over product attributes and that some of them are not observable to

(the vertical attribute) actually may benefit from maintaining consumer ignorance about their product's quality. Whether this happens depends on whether the elasticity of demand for a seller's product would become more, rather than less, elastic after disclosure. Whether the demand for products become more or less elastic with disclosure depends on consumer preferences over both the vertical and horizontal attributes of products. If the demand for the product becomes more elastic, disclosure can result in intense price competition with their (lower-quality) rivals, causing prices and profits to fall. As such, no firm in a market may find it in its interest to voluntarily disclose the quality of their products, even though disclosure costs are zero, sellers know their products and consumers have no difficulty in interpreting the information about product quality if it were disclosed.

Our paper is indirectly related to the literature on horizontal and vertical differentiation in that these papers worry about the tension between the benefits to a firm differentiating from its competitors to minimize competition versus the potential gains to minimizing differences in order to maximize one's attractiveness to large numbers of consumers. While we assume that the attributes of products are exogenously given to sellers, we note that the decisions of firms about whether to disclose the quality of their products are similar to firms' decisions to differentiate their products along that dimension.

Our paper also is related to the literature on informative advertising.[6] In particular, Grossman and Shapiro (1984) consider a model of informative advertising in which they consider the strategic effect of firms' use of providing truthful information about their location. Grossman and Shapiro find that in a market with differentiated products, firms' profits may in-

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consumers prior to purchase.

[6] More generally, informative advertising refers to truthful information supply about products' prices, attributes, etc. This is in contrast to prestige advertising, which refers to the provision of information that might alter consumers' valuation of the advertised products, e.g., Pepsi claims to be for "new generation" in ads.

crease with the cost of advertising since an increase in advertising costs reduces advertising and thus increases informational product differentiation—this allows firms to raise prices.[7] This strategic effect, in essence, is similar to the one that we argue can discourage firms from voluntarily disclosing the quality of their products.

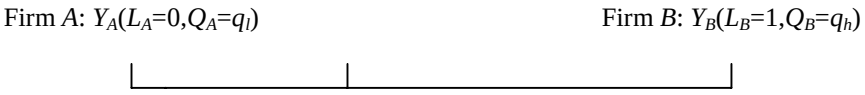
This remainder of the paper is organized as follows. In section 2, we develop a duopoly model of two firms that each sell products having a horizontal attribute (location) and a vertical attribute (quality), where we assume that the latter attribute is not readily observable by consumers prior to purchase. We describe the structure of consumer preferences over these attributes, the nature of disclosure options for the firms and the structure of the game that characterizes consumer product choice and the quality disclosure and pricing decisions of firms. We characterize the equilibrium for this two-stage game under alternative assumptions about the distribution of consumer preferences and disclosure mechanisms. We establish that whether a firm chooses to voluntarily disclosure its quality depends on the nature of the interactions in preference orderings over the two attributes of the products. In section 3, we provide an analysis and an intuitive explanation of how disclosure of quality can affect the elasticity of demand for a firm's product and, as a result, its willingness to voluntarily disclose the quality of their product to consumers. In section 4, we briefly describe the policy and potentially testable implications of our model depending on whether quality disclosure is mandatory or at the discretion of firms. Section 5 offers some concluding observations.

[7] Note this "informational product differentiation" view can be contrasted with the "search costs" view, which argue that better information flow (due to advertising, information supply from government or other authorities, etc) will reduce consumers' search costs, increase price elasticity of demand, cause tenser price competition from firms and reduce market price levels.

## 2. The Model[8]

### *2.1 Set Up*

In this section, we describe the set up of the model we analyze. We consider a duopoly model in which two firms sell products with two dimensions or attributes. Each firm, Firm *A* and Firm *B*, is endowed with a product $Y_j$, ($j = A, B$) which has two attributes. Following the literature on product differentiation, we assume that these products differ across firms in their *horizontal* attribute,[9] location (denoted by $L$), and in their *vertical* attribute,[10] the quality of their product (denoted by $Q$), so that $Y_j = Y(L_j,Q_j)$. We assume that the attributes of a firm's product are exogenously given to them and cannot be altered. With respect to a firm's horizontal attribute, firms are located vis-à-vis consumers at the end points of a linear city. (See the following diagram.) Let $L_j$ denote ($0 \leq L_j \leq 1$) denote the location of the $j^{th}$ firm ($j = A, B$) in the linear city, where we assume that Firm *A*'s location is fixed at $L_A = 0$ and Firm *B*'s at $L_B = 1$. With respect to the vertical attribute, we assume that Firm *A* sells a low quality product ($Q_A = q_l$), while Firm *B* sells one a high quality one ($Q_B = q_h$). We denote the difference, or spread, in quality between these two products by $\Delta$, i.e., $\Delta \equiv q_h - q_l > 0$.




**The Linear City**

[8] See Corts (1998) for how price discrimination can lead to an all-worse-off for firms ranking consumer groups differently by their elasticities.

[9] In the industrial organization literature, location is used as a typical example of horizontal attributes of a product, which means, holding prices constant, different consumers have different preferences over the attribute. For example, given the same price, some consumers may buy a black Honda Accord, while some may buy a silver one.

[10] In the industrial organization literature, the quality of a product is referred to as a "vertical" attribute of a product. Vertical attributes of products are characterized by the following condition: holding prices constant, all consumers have the same preference order over this attribute. For example, all consumers prefer a 6-cylinder Honda Accord to a 4-cylinder one, holding the prices of the two different automobiles constant.

Consumers are assumed to be uniformly distributed along the linear city, where $X_i$ ($0 \leq X_i \leq 1$) denotes the $i^{th}$ consumer's location, i.e., consumers differ with respect to their proximity to the two firms. Consumers care about both their distance from products, their quality, if known to consumers, and the prices of products, $P_j$, $j = A, B$. More precisely, the $i^{th}$ consumer values any given product according to the following utility function:

$$U_{ij}\left(\left|L_j - X_i\right|, Q_j, P_j\right) \equiv V + \theta^i Q_j - \lambda D_{ij} - P_j \tag{1}$$

where $V$ is the stand-alone value of consuming either good (instead of consuming the outside good), the disutility of paying price $P_j$ for product $j$ is normalized to 1 and $D_{ij} \equiv |L_j - X_i|$ denotes the distance of the $i^{th}$ consumer from the $j^{th}$ product. (We normalize the utility from the outside good is 0 and assume $V$ is high enough that no consumer will choose it.) As specified in (1), the utility a consumer derives from a product is decrease in her distance from it, where $\lambda > 0$.[11] Thus, as is the usual set up for horizontal attributes, consumers obtain the same disutility per unit of distance they must travel to purchase a particular product but they differ with respect to the distances they have to travel. With respect to the quality of a product, we allow different consumers to value this product attribute differently. To capture this source of consumer heterogeneity in a parsimonious way, assume that there are two types of consumers: those quality-lovers who value quality, i.e., $\theta^i = \theta$, where $\theta > 0$, and quality-neutrals, who do not value it, i.e., $\theta^i = \theta_0$, where we set $\theta_0 = 0$ as a normalization. Thus, it follows that $\theta$ measures the difference, or spread, in this willingness to pay between the two types of consumers, since $\theta - \theta_0 = \theta - 0 = \theta$.

A crucial dimension of the heterogeneity of consumers and their preferences for prod-

[11] The greater the value of $\lambda$, the harder it is for consumers to travel from one end of the city to the other. Thus $\lambda$ is a measure of consumer heterogeneity over the horizontal attribute of products.

ucts concerns the joint distribution of their location (and, thus, distance from products) and their tastes for product quality. At one extreme, consumers' location and their tastes for quality may be uncorrelated, i.e., $\Pr(X_i, \theta^i) = \Pr(X_i)\Pr(\theta^i)$. This is but one possible distribution. The distribution of consumer location and preferences for quality, in fact, may be correlated. To allow for this possibility in a tractable way, let consumer's location and quality preferences be distributed according to the following conditional probability functions:

$$\Pr\left(\theta^i = \theta \middle| X\right) = \beta X + \frac{1-\beta}{2} \tag{2}$$

$$\Pr\left(\theta^i = \theta_0 \middle| X\right) = -\beta X + \frac{1+\beta}{2} \tag{3}$$

where $\beta \in$ [-1,1].[12] The nature and degree of correlation in consumer's tastes over a product's horizontal and vertical attributes varies with the parameter, $\beta$. In particular, consider the following three cases:

Case I: $\beta = -1 \Rightarrow \Pr\left(\theta^i = \theta \middle| X_i\right) = 1 - X_i$ and $\Pr\left(\theta^i = \theta_0 \middle| X_i\right) = X_i$

Case II: $\beta = 0 \Rightarrow \Pr\left(\theta^i = \theta \middle| X_i\right) = \frac{1}{2}$ and $\Pr\left(\theta^i = \theta_0 \middle| X_i\right) = \frac{1}{2}$

Case III: $\beta = 1 \Rightarrow \Pr\left(\theta^i = \theta \middle| X_i\right) = X_i$ and $\Pr\left(\theta^i = \theta_0 \middle| X_i\right) = 1 - X_i$

In Case I, quality-lovers are more likely to live close to Firm $A$ ($L_A$=0), which is the low-quality product ($Q_A$=$q_l$). In this case, we say that $X$ and $\theta^i$ are "negatively" correlated. In Case III, quality-neutrals are more likely to live close to Firm $A$ and we say that $X$ and $\theta^i$ are "positively" correlated. Finally, in Case II, quality-lovers and quality-neutrals are equally likely to live close to either product and we say that $X$ and $\theta^i$ are uncorrelated or are "orthogonal" to one another. As $\beta$ varies from -1 to 1, the relationship between $X$ and $\theta^i$ goes from being nega-

tively to positively correlated.

To complete the model, we need to take a stand on what consumers and firms know about product attributes. We assume consumers possess perfect information about their preferences over quality have perfect information, their own locations, and the locations of firms. However, consumers are assumed not to know, *a priori*, the quality of a particular firm's product, at least not without a firm disclosing it. Consumers do know the distribution of quality levels in the market.[13] That is, without additional information, consumers believe both products are of the same quality, i.e., $E(Q) = \frac{q_h + q_l}{2}$. Furthermore, we assume that consumers do not know how other consumers are distributed with respect to their tastes, i.e., they do not know the conditional probabilities in (2) and (3). In one sense, the latter assumption—which restricts the ability of consumers to make inferences about product quality from knowledge of where consumers are located and firms' disclosure decisions—does not seem unreasonable. However, relative to formal models of product differentiation and disclosure, this assumption does severely restrict what is common knowledge and, as such, does severely limit the ability of consumers to make inferences about product qualities. We leave to future work any relaxation of this assumption. Finally, with respect to the sellers (firms), we assume that they know the quality of their rival's product and they each know the distribution of consumer tastes, i.e., they do know (2) and (3).

### *2.2 Disclosure Technology and Game Structure*

Suppose there exists a costless truthful, accurate and credible disclosure mechanism for

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[12] It follows from the specifications of the conditional probabilities in (2) and (3) that $\Pr(\theta_0|X) + \Pr(\theta|X) = 1$.

[13] This means, consumers know that a given firm's product is either high or low quality, and both levels of quality are offered in the market.

sellers to disclose the quality dimension of their products. For example, there may be a non-profit certification agency offering free services to firms who want to disclose their product quality. If both firms do not use this mechanism, consumers have no way to find out true product quality. However, if either firm stands out and discloses its quality, consumers know the quality of this firm as well as the other firm.[14]

To characterize the quality disclosure problem, we use a two-stage dynamic game. In the first stage, both firms make disclosure decisions simultaneously. In the second stage, firms engage in Bertrand competition to maximize profits and consumers choose which product to purchase so as to maximize their utility, where their valuations of these products are conditional on product prices and what they know about the quality of these products.

The essence of this two-stage game is that each firm makes its first-stage, disclosure decisions, considering the possible second-stage price decisions of all firms in the game. We solve for a subgame perfect Nash equilibrium using backward induction. That is, a firm evaluates its payoff (profits) in the second stage under various information scenarios, which are determined by firms' disclosure decisions in the first stage, and then eliminates the first-stage strategy that yields its worse final payoff, taking its rival's first-stage and second-stage responses into consideration. By construction, there can only be two information scenarios—one in which neither firm discloses the quality of its product so that consumers have no information about product quality and the other in which one or both firms disclose their quality so that consumers have full information about product quality in the market. We refer to the payoffs under the first scenario as "non-disclosure outcomes" and those in the second-scenario as "disclosure outcomes." As illustrated in the following table, if both firms choose not to disclose,

[14] For example, if a high-quality firm discloses itself to be of high quality, consumers will know the other firm in the market is of low-quality, since consumers know the quality distribution. The same logic applies in reverse, i.e.,

they are face the non-disclosure outcomes. If either firm discloses, they both face disclosure outcomes, regardless of whether the other firm chooses to disclose or not. A firm's disclosure decision boils down to comparing the profit it would receive under the disclosure and non-disclosure outcomes. If each firm's payoff associated with the non-disclosure outcomes is worse than those in the disclosure case, both will choose not to disclose.[15] If the latter happens, the subgame-perfect Nash equilibrium will be (non-disclosure, non-disclosure).

**Firm *A***

| **Firm *B*** | | **Non-Disclosure** | **Disclosure** |
|---|---|---|---|
| | **Non-Disclosure** | Non-disclosure outcomes | Disclosure outcomes |
| | **Disclosure** | Disclosure outcomes | Disclosure outcomes |

In what follows, we will show how the outcomes—and, as a result, the equilibrium—depend on the assumptions made about the nature of consumer heterogeneity, i.e., different values of $\beta$ in (2) and (3).

### *2.3 Firm Outcomes under Non-Disclosure*

Consider first the purchase choices of consumers when no firm opts to disclose the quality of its product. Since consumers can not tell the quality difference of two products, a consumer will only care about prices and transportation costs and will purchase product $Y_A$ [$=Y(0,q_l)$] if and only if $2\lambda X \leq P_B - P_A + \lambda$. Thus, consumers who live close to Firm *A* will tend to buy $Y_A$, holding prices of both products constant. This is the standard result in the Hotelling model of product differentiation. It follows that the best-response functions for the two firms

a low-quality firm discloses itself to be low-quality, allowing consumers to infer that the other firm is high-quality.

[15] We assume if a firm is indifferent between non-disclosure and disclosure, it always chooses non-disclosure. A useful way to think about this is that disclosure is associated with an arbitrarily small cost.

are

$$P_A^{BR,non-disclosure} = 0.5(P_B + \lambda) \tag{4}$$

$$P_B^{BR,non-disclosure} = 0.5(P_A + \lambda) \tag{5}$$

and that, in equilibrium, the prices charged by the two firms are

$$P_A^{\cdot,non-disclosure} = \lambda = P_B^{\cdot,non-disclosure}. \tag{6}$$

That is, the two firms charge the same price, split the market equally, and each earns a profit of $0.5\lambda$.[16]

### *2.4 Firm Outcomes under Disclosure*

Now consider the case when either firm chooses to use the disclosure mechanism to disclose the quality of its product, which results in consumers having perfect information about the quality of products offered in the market. We consider the disclosure outcomes under alternative assumptions about consumer preferences and compare them to the non-disclosure outcomes derived above. Because $\theta^i$ takes on one of two values, we have:

- If a consumer is quality-neutral ($\theta^i = \theta_0 = 0$), she will buy the product with lower quality $[Y_A = Y(0,q_l)]$ if and only if $X_i \le \frac{P_B - P_A + \lambda}{2\lambda}$ and the high-quality product $[Y_B = Y(1,q_h)]$ if $X_i > \frac{P_B - P_A + \lambda}{2\lambda}$.
- If a consumer is quality-loving ($\theta^i = \theta > 0$), will buy the low-quality product $Y_A$ if and only if $X_i \le \frac{P_B - P_A + \lambda - \theta\Delta}{2\lambda}$ and the high-quality product $Y_B$ otherwise.

[16] Think about restaurants: tastes can be viewed as the horizontal attribute, while hygiene quality as vertical attribute. In a circumstance that restaurants have no credible method to reveal their hygiene quality to consumers, or they choose not to reveal even if such a mechanism exists, they may still earn positive profits, competing over prices and tastes.

These cases are illustrated in Figure 1. The horizontal axis represents the location of consumers relative to consumers, while the vertical axis represents the probability that a quality-loving consumer lives at location $X$. The (negatively-sloped) dashed line that cuts the figure divides the ($X$, Pr($\theta$)) space into quality-lover (Areas $C_1$ and $C_4$) and quality-neutral (Areas $C_2$ and $C_3$) consumers. The figure depicts the situation in which $X$ and $\theta^i$ are negatively correlated over consumers. The shaded area—the sum of $C_1$ and $C_2$—equals $s_A$, the proportion of consumers who will buy the lower-quality product $Y_A$. The unshaded area—the sum of $C_3$ and $C_4$—equals $s_B$, the proportion buying the higher-quality product, $Y_B$. Algebraically, these market shares for the two firms are given by:

$$\begin{aligned} s_A &= area(C_1) + area(C_2) \\ &= \frac{1}{2}\left(\frac{1-\beta}{2} + \beta\frac{P_B - P_A + \lambda - \theta\Delta}{2\lambda} + \frac{1-\beta}{2}\right)\left(\frac{P_B - P_A + \lambda - \theta\Delta}{2\lambda}\right) \\ &\quad + \frac{1}{2}\left(1 - \frac{1-\beta}{2} + 1 - \beta\frac{P_B - P_A + \lambda}{2\lambda} - \frac{1-\beta}{2}\right)\left(\frac{P_B - P_A + \lambda}{2\lambda}\right) \\ &= \left(1 - \frac{\beta\theta\Delta}{2\lambda}\right)\left(\frac{P_B - P_A + \lambda}{2\lambda}\right) + \frac{\beta\theta^2\Delta^2}{8\lambda^2} - (1-\beta)\frac{\theta\Delta}{4\lambda} \end{aligned} \tag{7}$$

$$\begin{aligned} s_B &= area(C_3) + area(C_4) = 1 - s_A \\ &= -\left(1 - \frac{\beta\theta\Delta}{2\lambda}\right)\left(\frac{P_B - P_A + \lambda}{2\lambda}\right) - \frac{\beta\theta^2\Delta^2}{8\lambda^2} + (1-\beta)\frac{\theta\Delta}{4\lambda} + 1 \end{aligned} \tag{8}$$

and, assuming there is no costs of production, the profit functions for both firms are given by:

$$\Pi_A = P_A s_A \tag{9}$$

$$\Pi_B = P_B s_B \tag{10}$$

To ensure that there are maximal values of profit functions, that prices are strategically complementary, and that there is a unique, stable price equilibrium, we assume that $\theta\Delta \leq \lambda$. That is, the assumption $\theta\Delta \leq \lambda$ ensures that the profit functions are well defined.

The following first-order conditions characterize the firms' optimization problems:

$$s_A - P_A\left[\frac{1-\frac{\beta\theta\Delta}{2\lambda}}{2\lambda}\right]=0\,, \tag{11}$$

$$s_B - P_B\left[\frac{1-\frac{\beta\theta\Delta}{2\lambda}}{2\lambda}\right]=0\,. \tag{12}$$

The conditions in (11) and (12) imply the following best-response (BR) functions:

$$P_A^{BR,disclsoure}=\frac{1}{2}\left(P_B+\lambda+\frac{\beta\theta^2\Delta^2-2\lambda(1-\beta)\theta\Delta}{4\lambda-2\beta\theta\Delta}\right)=\frac{1}{2}\left(P_B+\lambda-\frac{1}{2}\theta\Delta(1-\omega)\right) \tag{13}$$

$$P_B^{BR,disclosure}=\frac{1}{2}\left(P_A+\lambda+\frac{-\beta\theta^2\Delta^2+2\lambda(1+\beta)\theta\Delta}{4\lambda-2\beta\theta\Delta}\right)=\frac{1}{2}\left(P_A+\lambda+\frac{1}{2}\theta\Delta(1+\omega)\right), \tag{14}$$

where $\omega=\frac{2\lambda\beta}{2\lambda-\beta\theta\Delta}$, and the equilibrium prices for the two products are given by:

$$P_A^{\bullet,disclosure}=\lambda+\frac{\theta\Delta}{6}\left(\frac{6\lambda\beta-(2\lambda-\beta\theta\Delta)}{2\lambda-\beta\theta\Delta}\right)=\lambda+\frac{\theta\Delta}{2}\left(\omega-\frac{1}{3}\right) \tag{15}$$

$$P_B^{\bullet,disclosure}=\lambda+\frac{\theta\Delta}{6}\left(\frac{6\lambda\beta+(2\lambda-\beta\theta\Delta)}{2\lambda-\beta\theta\Delta}\right)=\lambda+\frac{\theta\Delta}{2}\left(\omega+\frac{1}{3}\right). \tag{16}$$

It follows from (15) and (16) that:

$$\begin{aligned} P_A^{\bullet,disclosure}+P_B^{\bullet,disclosure}&=\frac{2\lambda}{\beta}\omega \\ P_B^{\bullet,disclosure}-P_A^{\bullet,disclosure}&=\frac{\theta\Delta}{3} \end{aligned}\,.$$

It also follows from (15) and (16) that that the profits of the two firms under disclosure are:

$$\Pi_A^{\bullet,disclosure}=P_A^{\bullet,disclosure}s_A^{\bullet}=\frac{1}{2}\lambda\left[1+\frac{\theta\Delta}{2\lambda}\left(\omega-\frac{1}{3}\right)\right]\left[1+\frac{\theta\Delta}{2\lambda}\left(\frac{\beta\theta\Delta}{6\lambda}-\frac{1}{3}\right)\right] \tag{17}$$

$$\Pi_B^{\bullet,disclosure}=P_B^{\bullet,disclosure}s_B^{\bullet}=\frac{1}{2}\lambda\left[1+\frac{\theta\Delta}{2\lambda}\left(\omega+\frac{1}{3}\right)\right]\left[1+\frac{\theta\Delta}{2\lambda}\left(-\frac{\beta\theta\Delta}{6\lambda}+\frac{1}{3}\right)\right] \tag{18}$$

### *2.5 Firms' Equilibrium Quality Disclosure Decisions*

Comparing the disclosure outcomes with non-disclosure outcomes, $P_A^{\bullet,non-disclosure} = P_B^{\bullet,non-disclosure} = \lambda$ and $\Pi_A^{\bullet,non-disclosure} = \Pi_B^{\bullet,non-disclosure} = \frac{1}{2}\lambda$, we are able to show:

1) When $-\frac{2\lambda}{2\lambda+\theta\Delta} \le \omega < -\frac{1}{3}$, equivalently, $-1 \le \beta < \frac{-2\lambda}{6\lambda-\theta\Delta}$,[17] disclosure by either firm will cause both prices to be lower than those associated with the non-disclosure outcome.

2) When $-\frac{1}{3} \le \omega \le \frac{1}{3}$, equivalently, $\frac{-2\lambda}{6\lambda-\theta\Delta} < \beta < \frac{2\lambda}{6\lambda+\theta\Delta}$,[18] disclosure by either firm will cause $P_B$ to rise and $P_A$ to fall relative to the non-disclosure case.

3) When $\frac{1}{3} < \omega \le \frac{2\lambda}{2\lambda-\theta\Delta}$, equivalently, $\frac{2\lambda}{6\lambda+\theta\Delta} < \beta \le 1$, disclosure by either firm will cause both prices to increase relative to the non-disclosure case.

Meanwhile,

1) When $-\frac{2\lambda}{2\lambda+\theta\Delta} \le \omega < -\frac{5}{6}$,[19] equivalently, $-1 \le \beta < \frac{-10\lambda}{12\lambda-5\theta\Delta}$, disclosure by either firm

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[17] It can be shown that the expression $\frac{-2\lambda}{6\lambda-\theta\Delta}$ is bounded from above and below as follows:

$$-\frac{2}{5} \le \frac{-2\lambda}{6\lambda-\theta\Delta} \le -\frac{1}{3}.$$

[18] It can be shown that: $0 < \frac{2\lambda}{6\lambda+\theta\Delta} \le \frac{1}{3}$.

[19] When $-\frac{2\lambda}{2\lambda+\theta\Delta} \le \omega < -\frac{5}{6}$, we have $-\frac{2}{3} \le \omega + \frac{1}{3} < -\frac{1}{2}$ and $\frac{1}{3} < -\frac{\beta\theta\Delta}{6\lambda} + \frac{1}{3} \le \frac{1}{2}$. It follows that

$$0 < \frac{\theta\Delta}{2\lambda}\left(-\frac{\beta\theta\Delta}{6\lambda}+\frac{1}{3}\right) < -\frac{\theta\Delta}{2\lambda}\left(\omega+\frac{1}{3}\right)$$

and one can show that:

$$\Pi_B^{\bullet,disclosure} = \frac{1}{2}\lambda\left[1+\frac{\theta\Delta}{2\lambda}\left(\omega+\frac{1}{3}\right)\right]\left[1+\frac{\theta\Delta}{2\lambda}\left(-\frac{\beta\theta\Delta}{6\lambda}+\frac{1}{3}\right)\right] < \frac{1}{2}\lambda\left[1+\frac{\theta\Delta}{2\lambda}\left(\omega+\frac{1}{3}\right)\right]\left[1-\frac{\theta\Delta}{2\lambda}\left(\omega+\frac{1}{3}\right)\right] < \frac{1}{2}\lambda.$$

will cause both profits to be lower than those associated with the non-disclosure outcome.

2) When $-\frac{5}{6} \le \omega \le \frac{11}{15}$, equivalently, $\frac{-10\lambda}{12\lambda - 5\theta\Delta} \le \beta \le \frac{22\lambda}{30\lambda + 11\theta\Delta}$, disclosure by either firm will cause $\Pi_B$ to rise and $\Pi_A$ to fall relative to the non-disclosure case.

3) When $\frac{11}{15} < \omega \le \frac{2\lambda}{2\lambda - \theta\Delta}$,[20] equivalently, $\frac{22\lambda}{30\lambda + 11\theta\Delta} < \beta \le 1$, disclosure by either firm will cause both profits to increase relative to the non-disclosure case.

As these results make clear, the equilibrium prices chosen by the firms under product quality disclosure depend on the distribution of consumers' location and their preferences for quality. As the correlation of $X$ and $\theta^i$ goes from being negative to positive, disclosure by either firm will, in terms of profits, first make both worse-off, then make the firm with the low-quality product worse-off while making the firm with the high-quality product better-off, and, finally, make both firms better-off, relative to the non-disclosure case. More formally, we characterize the following proposition concerning the disclosure decisions of firms when products have multiple attributes:

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At the same time when $-\frac{2\lambda}{2\lambda + \theta\Delta} \le \omega < -\frac{5}{6}$, we have $\omega - \frac{1}{3} < 0$ and $\frac{\beta\theta\Delta}{6\lambda} - \frac{1}{3} < 0$, and

$$\Pi_A^{*,disclosure} = \frac{1}{2}\lambda\left[1 + \frac{\theta\Delta}{2\lambda}\left(\omega - \frac{1}{3}\right)\right]\left[1 + \frac{\theta\Delta}{2\lambda}\left(\frac{\beta\theta\Delta}{6\lambda} - \frac{1}{3}\right)\right] < \frac{1}{2}\lambda.$$

[20] When $\frac{11}{15} < \omega \le \frac{2\lambda}{2\lambda - \theta\Delta}$, we have $\omega - \frac{1}{3} > \frac{2}{5}$ and $\frac{\beta\theta\Delta}{6\lambda} - \frac{1}{3} \ge -\frac{1}{3}$. Then we can show:

$$\Pi_A^{*,disclosure} = \frac{1}{2}\lambda\left[1 + \frac{\theta\Delta}{2\lambda}\left(\omega - \frac{1}{3}\right)\right]\left[1 + \frac{\theta\Delta}{2\lambda}\left(\frac{\beta\theta\Delta}{6\lambda} - \frac{1}{3}\right)\right] > \frac{1}{2}\lambda\left[1 + \frac{\theta\Delta}{2\lambda}\left(\frac{2}{5}\right)\right]\left[1 + \frac{\theta\Delta}{2\lambda}\left(-\frac{1}{3}\right)\right]$$

$$= \frac{1}{2}\lambda\left(1 + \frac{\theta\Delta}{5\lambda}\right)\left(1 - \frac{\theta\Delta}{6\lambda}\right) = \frac{1}{2}\lambda\left[1 + \frac{\theta\Delta}{30\lambda}\left(1 - \frac{\theta\Delta}{\lambda}\right)\right] > \frac{1}{2}\lambda$$

At the same time when $\frac{11}{15} < \omega \le \frac{2\lambda}{2\lambda - \theta\Delta}$, we have $\omega + \frac{1}{3} > 0$ and $-\frac{\beta\theta\Delta}{6\lambda} + \frac{1}{3} > 0$, and

$$\Pi_B^{*,disclosure} = \frac{1}{2}\lambda\left[1 + \frac{\theta\Delta}{2\lambda}\left(\omega + \frac{1}{3}\right)\right]\left[1 + \frac{\theta\Delta}{2\lambda}\left(-\frac{\beta\theta\Delta}{6\lambda} + \frac{1}{3}\right)\right] > \frac{1}{2}\lambda.$$

**PROPOSITION 1:** *For multi-attribute products, with at least one attribute (quality) that is not immediately observed by consumers, the decision of one (or both) firms to disclosure the quality of their product can lead to the prices of both firms' products to decline and, thus, profits to decline. As a result, both firms with private information about the quality of their products may choose not to disclose.*

***Proof*:** As long as $\omega < -\frac{1}{3}$, i.e., $\beta < \frac{-2\lambda}{6\lambda - \theta\Delta}$, disclosure from either firm will cause the resulting prices of both firms to decrease relative to their non-disclosure levels. Profits will decrease for both firms when $\beta$ is negative enough, that is, when $\beta < \frac{-10\lambda}{12\lambda - 5\theta\Delta}$. Under this circumstance, either firm, in anticipation of its rival's response and the price equilibrium, following disclosure, will choose not to disclose. The subgame-perfect Nash equilibrium is (non-disclosure, non-disclosure). Q.E.D.

To better understand this proposition, consider how the firms' best-response functions under disclosure are affected by the nature of the correlation between consumer location and their preferences for quality and how they differ from the response functions in the non-disclosure case. When $\beta$ = -1, the best-response functions are:

$$P_A^{BR,\beta=-1} = \frac{1}{2}\left[ P_B + \lambda - \frac{1}{2}\theta\Delta\left(1 + \frac{2\lambda}{2\lambda + \theta\Delta}\right)\right] \tag{19}$$

$$P_B^{BR,\beta=-1} = \frac{1}{2}\left[ P_A + \lambda + \frac{1}{2}\theta\Delta\left(1 - \frac{2\lambda}{2\lambda + \theta\Delta}\right)\right], \tag{20}$$

while if $\beta$ = 1, the best-response functions are:

$$P_A^{BR,\beta=1} = \frac{1}{2}\left[ P_B + \lambda - \frac{1}{2}\theta\Delta\left(1 - \frac{2\lambda}{2\lambda - \theta\Delta}\right)\right] \tag{21}$$

$$P_B^{BR,\beta=1} = \frac{1}{2}\left[ P_A + \lambda + \frac{1}{2}\theta\Delta\left(1 + \frac{2\lambda}{2\lambda - \theta\Delta}\right)\right]. \quad (22)$$

These two cases, along with the response functions in the non-disclosure case, are illustrated in Figure 2. In the general case, the best-response functions are a weighted average of those given in (19)-(20) and (21)-(22), respectively. That is:

$$P_A^{BR} = \alpha P_A^{BR,\beta=-1} + (1-\alpha) P_A^{BR,\beta=1} \quad (23)$$

and

$$P_B^{BR} = \alpha P_B^{BR,\beta=-1} + (1-\alpha) P_B^{BR,\beta=1}. \quad (24)$$

where $\alpha = \frac{1-\beta}{2}\frac{2\lambda + \theta\Delta}{2\lambda - \beta\theta\Delta}$ and $\alpha \in [0,1]$.[21] Notice that the point of intersection of $P_A^{BR}$ and $P_B^{BR}$ is the price equilibrium. The above decomposition shows that any point along the bold line *LH* can be supported as an equilibrium, given that $\alpha \in [0,1]$.[22] Which equilibrium will be realized depends solely on the correlation between *X* and $\theta^i$. If, for example, *X* and $\theta^i$ are positively correlated ($\beta$ = 1), then $\alpha$ = 1, and the equilibrium is at point *H* (the north-east corner of line *LH*). There, the prices charged by both firms are higher under disclosure than those charged under non-disclosure. If *X* and $\theta^i$ are negatively correlated ($\beta$ = -1), then $\alpha$ = 0 and the equilibrium would be at point *L*, where the prices of both products are lower under disclosure than with non-disclosure.

As can be seen in Figure 2, the best-response curve for $Y_A$ can shift downward with

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[21] Note that $\frac{\partial\alpha}{\partial\beta} = -\frac{4\lambda^2 - \theta^2\Delta^2}{2(2\lambda - \beta\theta\Delta)^2} < 0$ either when $\beta$ = -1 and $\alpha$ = 1 or when $\beta$ = 1 and $\alpha$ = 0. Therefore $\alpha$ is bounded by 0 and 1.

[22] Since $P_B^{\bullet,disclosure} - P_A^{\bullet,disclosure} = \frac{\theta\Delta}{3}$, it follows that no matter how $\beta$ changes, the resulting equilibria form a straight line and any point on this line is a weighted average of two end points.

disclosure by more than the corresponding function for $Y_B$ shifts upward. This can happen when $\beta$ is sufficiently negative. In this case, both firms are worse off, i.e., each firm's prices and profits are lower than if neither firm disclosed to consumers the quality of its product. As a result, neither firm has an incentive to voluntarily disclose the quality of its product.

### *2.6 An Illustration*

To help clarify the implications of Proposition 1, we consider the following hypothetical situation to illustrate the results from our model for firms' decision-making with respect to quality disclosure. Suppose there are two restaurants in a market.[23] One restaurant is a fast food outlet that specializes in hamburgers. The other is a French restaurant that features escargot, among other dishes. Two types of consumers populate this market: students and professors. At the same prices for a meal, we suppose that, on average, students prefer hamburgers, and thus fast food restaurants, to French cuisine, while, on average, professors, who have more sophisticated palettes, prefer escargot, and, thus the French restaurant, relative to fast food.

The restaurants also differ with respect to the hygiene practiced in their preparation of food. Suppose, in fact, that the fast food restaurant maintains a very sanitary kitchen, while the French restaurant's hygienic practices are more lax. Neither type of consumers, on their own, can readily determine the hygienic practices of either restaurant. While consumers do not know the hygiene practices of either firm, restaurants are inspected by the local Public Health department. We assume that the findings of these inspections are accurate and credible, but that they are not disclosed to the general public.[24] Rather, the department issues warnings when they find poor hygiene practices and provide this information only to the restaurants. At the same

[23] This example is inspired by a recent paper by Jin and Leslie (2002), who consider restaurants in the Los Angeles market and their hygiene practices, as measured by Los Angeles County's Department of Public Health.

[24] For sake of this example, assume that restaurants cannot be closed down by the Public Health department for

time, restaurants could choose to disclose the hygiene ratings they receive, by posting them at the entrance of their restaurants.[25]

When will one or more of the restaurants choose to post their ratings? The above analysis indicates that this depends on the distribution of consumer tastes for the two types of cuisine *and* for the hygiene practices of restaurants. Recall that professors, on average, are more likely to prefer French cuisine to fast food and, on average, students have just the opposite preferences. Consider the case where, on average, students have stronger preferences for better hygiene practices in the preparation of their food than do professors.[26] In essence, preferences for hygiene and tastes for food are "positively" correlated, as those who have stronger preferences for hygiene also prefer the taste of the more sanitary food and those who have weaker preferences for hygiene tend to prefer the taste of the less sanitary food. Under this distribution of preferences, we should expect the fast food restaurant to post its better hygiene rating for consumers to see. This will happen because these two restaurants, upon disclosure, become less substitutable for both students and professors than when consumers know nothing about hygiene. For students, the fast food restaurant offers the taste they prefer and better hygiene, which they also prefer under the assumed distribution of preferences. Professors, on the other hand, prefer the taste of French food and are less willing (than students) to pay for better hygiene; they are content to stay with the French restaurant. Thus, under the disclosure of restaurants' hygiene practices, the degree of price competition between the two restaurants actually may be reduced, due to the decline in substitutability between the two restaurants for

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bad hygiene practices.

[25] For example, the Los Angeles County Department of Public Health issued hygiene "grade cards" to restaurants and, in some areas of the county, allowed restaurants the choice of whether or not to display them. See Jin and Leslie (2002) for further details.

[26] Recall that we assumed in our model that both firms know about the distribution of preferences over both cuisine-type and hygiene.

the two types of consumers. Both firms potentially gain from this relaxation of competition. As a result, the fast food restaurant will find it in its self-interest to disclose its better hygiene practices, which will result in it achieving higher profits.

Under the above distribution of preferences, one finds that voluntary disclosure about product quality holds, as in the unraveling result of Grossman (1981) and Milgrom (1981). But now suppose that, on average, professors care more about the hygiene practices of restaurants than do students.[27] That is, while professors prefer French cuisine relative to fast foods, they also tend to prefer better hygiene—something that the French restaurant does not practice—and students, who prefer hamburgers, do not place high value on better hygienic practices, at which the fast food restaurant excels. Under this distribution of preferences in the population of potential patrons, will the fast food restaurant still want to post its better hygiene rating?

Consider what we would expect to happen if the fast food restaurant did disclose. Naturally, some professors, who value French food not as strongly as other professors (and/or who value hygiene quality more strongly than others) have incentive to switch to the fast food restaurant upon learning that it maintained better sanitary conditions than did the French restaurant. In response, the French restaurant may want to decrease its price to keep its consumer base. But this competition for dining customers will affect the fast food restaurant's market share, as some students, who do not care much about hygiene quality and who value hamburgers not as strongly as other students, would be willing to switch to the French restaurant for lowered prices. In turn, the fast food chain may also want to lower its price to keep its consumer base, which may induce further price-cutting by the French restaurant. In the end, both restaurants would end up with lower prices and profits if the fast food restaurant were to dis-

[27] This might arise because professors cannot afford to miss the classes they teach due to food poisoning while students do not mind missing a few of those classes, even if they have to spend the time in the student infirmary!

close. As a result, disclosing its better hygiene rating is not in the fast food restaurant's self-interest under this latter distribution of consumer preferences. Furthermore, neither will the French restaurant, since it also has nothing to gain from disclosing to consumers its poor hygiene practices. As a result, voluntary disclosure will not occur in this market, even though both professors and students would be better off by having this information prior to deciding where to dine.

What is central to this second scenario for our restaurant example is that consumers value both the horizontal attribute (taste, or time-saving, in the above example) and a vertical attribute (hygiene quality in the above example) of the product (a meal outside the home). If consumers know both attributes of the meals the two restaurants are serving, they will choose to trade off their preferred cuisine for sanitary conditions and either will need to be compensated for lower hygiene or unwilling to pay a higher price for something (better hygiene) that they do not value. In essence, this configuration of the preferences of consumers in the market can make disclosure undesirable for firms even with high quality, precisely because disclosure increases the substitutability between the two products.

### *2.7 Comparative Statics: The Role of Consumer Heterogeneity*

To this point, we have focused on how the incentives of firms to voluntarily disclose their unobserved quality to consumers varies with $\beta$, which characterizes the relationship between consumers' preferences for the observable and quality attributes of products. But, as we have noted at various points, our results with respect to when voluntary disclosure will occur also depend on $\lambda$, the "costs" to consumers of having to travel to purchase a product, and $\theta$, which is a measure of the heterogeneity of consumers' preferences for quality.[28] In this section,

[28] Recall that $\theta = \theta - \theta_0$, given that we normalize $\theta_0$ to zero.

we briefly consider how firms' prices, market shares and profits with and without disclosure of product quality varies as we vary these two aspects of consumer preferences.

Consider first, how firm pricing decisions under disclosure would change as we increase the differences, or spread, across consumers in their tastes for quality:

$$\frac{\partial P_A^{*,disclosure}}{\partial \theta} = \frac{\Delta}{2}\left(\frac{\omega^2}{\beta} - \frac{1+\theta}{3}\right) \tag{25}$$

$$\frac{\partial P_B^{*,disclosure}}{\partial \theta} = \frac{\Delta}{2}\left(\frac{\omega^2}{\beta} + \frac{1+\theta}{3}\right) \tag{26}$$

It can be shown that the above two derivatives will be negative when $\beta$ is sufficiently negative. This implies that under the conditions in which we have found that either firm is less likely to disclose its quality—i.e., when $\theta$ and $X$ are sufficiently negatively correlated—the more consumers are differentiated in their tastes for quality, the lower are the overall market price levels. The contrary case also holds. That is, when $\beta$ is sufficiently positive, increasing the spread in consumer tastes for quality tends to lead to not only disclosure but also higher overall market price levels.

Now consider how increasing the cost to consumers for the location attribute of a product, i.e., when consumers face higher travel costs. It can be shown that:

$$\frac{\partial P_A^*}{\partial \lambda} = 1 - \left(1 - \frac{2\lambda}{2\lambda - \beta\theta\Delta}\right)^2 > 0 \tag{27}$$

$$\frac{\partial P_B^*}{\partial \lambda} = 1 - \left(1 - \frac{2\lambda}{2\lambda - \beta\theta\Delta}\right)^2 > 0 \tag{28}$$

That is, the prices of products under disclosure increase with $\lambda$. Note, however, that this prediction also holds under the nondisclosure equilibrium, as prices increase with $\lambda$ in that case too. Thus, consumer heterogeneity with respect to the observed attributes of products tend to in-

crease product prices, whether or not consumers know about the (unobserved) quality attributes of these products.

We have shown that when product quality is disclosed to consumers, whether both firms may be made worse off—and, thus, do not have an incentive to disclose—depends on the nature of the heterogeneity in consumer preferences, both with respect to the joint distribution of $\theta$ and $X$, as well as the (univariate) distribution of tastes for quality (as measured by $\theta_1$). In the model, consumer heterogeneity with respect to tastes for quality were characterized in a very simple way, allowing for only two types of consumers. In the Appendix, we examine whether our findings with respect to firm prices, profits and incentives to disclose product quality are robust by considering a variant of our model in which we allow for a continuum of types of consumers with respect to their preferences over the quality attribute of products. We show that the overall thrust of our findings is not sensitive to this feature of the model.

## 3. Quality Disclosure, Product Substitution Patterns and Demand Elasticities

In the absence of disclosure of product quality, consumers are forced to choose products with less than full information about all attributes of a product. In general, this will lead to a mismatch of consumers and products. In contrast, full disclosure allows consumers to assess the entire bundle of attributes contained in each product and, as a result, more accurately assess their willingness to pay for each product. But, as the results in the previous section make clear, allowing consumers to make this assessment with complete information may not always be in the interests of firms. Such disclosure may make consumers more sensitive to the prices charged by firms, to the extent that knowledge of product quality, as well as its location, may cause consumers to trade-off the two as the firms vary the prices of their products. In this section, we characterize our findings concerning the incentives of firms to disclose product quality

in terms of what effect disclosure can have on the elasticities of demand for multi-attribute products.

As is well known from the literature on product differentiation, a firm has a strategic incentive to differentiate their product when such differentiation reduces the elasticity of demand for its product. Disclosure of the quality of its product can differentiate one firm's product from that of its competitor. But, the results derived in the previous section indicate that whether disclosure will reduce the price responsiveness of consumers for a firm's product (relative to no disclosure of product quality) depends on how consumers' tastes for quality and their location vis-à-vis firms are distributed in markets. To see this, we need to characterize the elasticities of demand for products $Y_A$ and $Y_B$ with and without quality disclosure.

Consider first the demand elasticities of demand for the two products under the non-disclosure equilibrium. In the general case where $P_A = P_B = P$, these elasticities are given by:

$$e_A^{non-disclosure}\left[\equiv -\frac{\partial s_A}{\partial P_A}\frac{P_A}{s_A}\bigg|_{non-disclsoure}\right] = \frac{P}{\lambda} = e_B^{non-disclosure}\left[\equiv -\frac{\partial s_B}{\partial P_B}\frac{P_B}{s_B}\bigg|_{non-disclosure}\right]. \qquad (29)$$

At the non-disclosure equilibrium, $P_A = P_B = \lambda$, it follows that $e_A^{non-disclosure} = e_B^{non-disclosure} = 1$. Note further that when the price of a product is below the equilibrium level ($\lambda$), both firms have an incentive to increase their prices since $e_j^{non-disclosure} < 1$, both firms will want to decrease their prices if their prices are greater than $\lambda$, since in that case $e_j^{non-disclosure} > 1$.

Under the disclosure equilibrium, the elasticities of demand for the two products are given by:

$$
\begin{aligned}
e_A^{disclosure} &= \frac{\frac{P_A}{2\lambda}\left(1-\frac{\beta\theta\Delta}{2\lambda}\right)}{\left(1-\frac{\beta\theta\Delta}{2\lambda}\right)\left(\frac{P_B-P_A+\lambda}{2\lambda}\right)+\frac{\beta\theta^2\Delta^2}{8\lambda^2}-(1-\beta)\frac{\theta\Delta}{4\lambda}} \\
&= \left(\frac{\beta}{2\lambda\omega}\right)\left(\frac{P_A}{\frac{\beta}{2\lambda\omega}(P_B-P_A+\lambda)+\frac{\beta\theta\Delta}{4\lambda}\left(1-\frac{1}{\omega}\right)}\right) \\
&= \frac{P_A}{(P_B-P_A+\lambda)+\frac{\theta\Delta}{2}(\omega-1)}
\end{aligned}
\tag{30}
$$

and

$$
\begin{aligned}
e_B^{disclosure} &= \frac{1}{2\lambda}P_B\frac{1-\frac{\beta\theta\Delta}{2\lambda}}{-\left(1-\frac{\beta\theta\Delta}{2\lambda}\right)\frac{P_B-P_A+\lambda}{2\lambda}-\frac{\beta\theta^2\Delta^2}{8\lambda^2}+(1-\beta)\frac{\theta\Delta}{4\lambda}+1} \\
&= \left(\frac{\beta}{2\lambda\omega}\right)\left(\frac{P_B}{-\frac{\beta}{2\lambda\omega}(P_B-P_A+\lambda)-\frac{\beta\theta\Delta}{4\lambda}\left(1-\frac{1}{\omega}\right)+1}\right) \\
&= \frac{P_B}{-(P_B-P_A+\lambda)-\frac{\theta\Delta}{2}(\omega-1)+\frac{2\lambda\omega}{\beta}}
\end{aligned}
\quad , \tag{31}
$$

respectively. Furthermore, at $P_A=P_B=\lambda$, $e_A^{disclosure}=\left(1+\frac{\theta\Delta}{2\lambda}(\omega-1)\right)^{-1}$, and $e_B^{disclosure}=$ $\left[-1-\frac{\theta\Delta}{2\lambda}(\omega-1)+\frac{2\omega}{\beta}\right]^{-1}$.

Consider what happens to the elasticities of demand for the two products when $X$ and $\theta$ are more negatively correlated. When $\beta<\frac{2\lambda}{2\lambda+\theta\Delta}$, $e_A^{disclosure}>1$, i.e., the elasticity of demand for the low-quality product is more than unitary elastic, so that when the qualities of products have been disclosed, Firm *A* will want to lower its price in order to avoid losing the consumers

it attracted when there is no disclosure. At the same time, $e_B^{disclosure} = \left[-1-\frac{\theta\Delta}{2\lambda}(\omega-1)+\frac{2\omega}{\beta}\right]^{-1} <$ 1,[29] which is why the best-response curve of the high-quality firm always shift up after disclosure. But, when $\beta$ is sufficiently negative, the elasticity of demand for the high-quality product, $e_B^{disclosure}$, will become greater than 1, as the low-quality firm lower its price relative to its non-disclosure level.[30] Traditional wisdom tells us greater demand elasticity is associated with more substitutability among products, and thus with more intense price competition among firms. Therefore revelation of a quality attribute, generating greater product substitutability and intensifying price competition in the market, might result in price decreases for all firms, and possibly, profit decreases for all firms. It follows that firms of high quality, out of strategic considerations, may try to avoid revelation of their true quality level.

Why do the elasticities of demand for the two products become greater (in absolute value) when *X* and $\theta^i$ are negatively correlated? As noted before, consumers in this case are systematically "mismatched" with respect to location and tastes for quality in that quality-lovers, on average, are located closer to the low-quality product (sold by Firm *A*) and quality-neutrals are located closer to the high-quality product (sold by Firm *B*). Upon disclosure, consumers are realize this mismatch and, as a result, are less willing to pay higher prices for products near to them than they were when location was the only attribute of the product upon which

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[29] This inequality is equivalent to $\beta > -\left(1-\frac{\theta\Delta}{2\lambda}\right)^{-1}$ and this is always true, as $-\left(1-\frac{\theta\Delta}{2\lambda}\right)^{-1}$ is less than -1 and $\beta \in$ [-1,1].

[30] When $P_B = \lambda$, $e_B^{disclosure} = \left[\frac{P_A}{\lambda}-2-\frac{\theta\Delta}{2\lambda}(\omega-1)+\frac{2\omega}{\beta}\right]^{-1}$. If $\beta < \frac{2\lambda}{\theta\Delta}\left(1-\left(2-\frac{P_A}{\lambda}-\frac{\theta\Delta}{2\lambda}\right)^{-1}\right)$, it follows that $e_B^{disclosure} > 1$. Hence we can see that when the low-quality firm lowers its price $P_A$ relative to its non-disclosure level $\lambda$, a sufficiently negative $\beta$ will make the elasticity for the high quality product greater than unity.

they based their product choice. They prefer to compensate for the mismatch in location and quality that they now face with lower prices and, as a result, are more price sensitive in their demand for products than when they were unaware of it.

The above discussion characterizes what happens to the elasticities of demand for each product when $X$ and are sufficiently negatively correlated. One can show that when $\beta$ is sufficiently positive, the elasticities of demand for the two products will be lower in absolute value—their demand curves will be steeper[31]—the disclosure equilibrium relative to those that prevail under non-disclosure. That is, when $\beta$ is sufficiently positive, firms are able to raise their prices given that the location of consumers vis-à-vis the two products is favorably matched with their tastes for quality.

To understand results derived above is to understand how demand elasticities would change with the disclosure of the quality attributes of these products under alternative assumptions about the structure of consumers' preferences. As noted in the introduction, the primary motivation for firms to differentiate their products is to reduce the degree of price competition with rivals selling otherwise similar products. To the extent that this is true, differentiating one's product should reduce the product's elasticity of demand, thereby allowing the firm to increase the product's price and still increase its profit. This logic is borne out in the no-disclosure-mechanism case considered above. Therein, from the consumers' perspective, both prod-

[31] Note that $\partial s_h/\partial P_h$ and $\partial s_l/\partial P_l$, which are the inverses of the slopes of the demand curves, are equal to:

$$\frac{\partial s_h}{\partial P_h} = \frac{\partial s_l}{\partial P_l} = -\frac{1}{2\lambda}\left(1 - \frac{\beta\theta\Delta}{2\lambda}\right),$$

Therefore, if $\beta < 0$, then $\left|\frac{\partial s_h}{\partial P_h}\right|$ and $\left|\frac{\partial s_l}{\partial P_l}\right|$ become bigger, and then the slopes of both demand curve become less steep; if $\beta > 0$, then $\left|\frac{\partial s_h}{\partial P_h}\right|$ and $\left|\frac{\partial s_l}{\partial P_l}\right|$ become smaller, and the slopes of both demand curve become steeper.

ucts are fully characterized by their locations and, by assumption, are fully differentiated, since the two firms are located at opposite ends of the linear city. With no disclosure about product quality, each firm faces a downward sloping demand curve for its product. Consumers closest to a particular firm having higher willingness to pay for its product than for the product of its rival and do not view the two products as perfect substitutes.[32] As a result, firms selling such a differentiated product may earn positive profits.[33] With this existing horizontal differentiation, a firm's incentive to differentiate along another dimension—in our case via disclosing the quality of its product—depends on what would happen to the elasticity of demand for its product if it (or the other firm) revealed the quality of its product and this, in turn, depends on the nature of the relationship, or correlation, of consumers' preferences over these product attributes.

In summary, the key message we try to convey can be phased as follows: in a world with existing product differentiation, revelation of another dimension of product differentiation might change the substitution patterns among products, which could intensify or alleviate competition, depending on how consumers' multidimensional preferences are distributed. Firms, even with high quality, out of strategic considerations, may want to avoid disclosure if consumers' better knowledge leads to more intense competition among firms.

## 4. Policy and Testable Implications

As has been noted by others, there are two immediate implications that follow if the

[32] At the individual level, for consumer *i*, who values this product more, this product is less substitutable than for consumer *i′*, who value it less. Consumer *i* is more "loyal" than *i′* to this product.

[33] The same logic holds for the case of a single vertical attribute. Note in a standard Bertrand model of vertical differentiation firms will earn zero profit if there is no quality difference; quality difference brings positive profit to both the low-quality firm and the high-quality firm. It follows that there are always incentives for firms of any quality to disclose.

"unraveling result" holds:

- Voluntary disclosure, as long as the disclosure is verifiable and of trivial costs, will achieve the same result as having mandatory disclosure requirement. Thus, we should not expect to see any changes in disclosure behaviors, prices, and profits of firms in markets for differentiated products when disclosure mechanisms—either from voluntary to mandatory or visa-versa—change.[34] This implication, for example, motivates the null hypothesis in the analysis of the implementation of restaurant report cards in Los Angeles County by Jin and Leslie (2001).
- Disclosed high-quality firms charge price premiums over non-disclosed firms, which are deemed as of inferior quality, i.e., non-disclosed firms lose from disclosure of their disclosed high-quality rivals. The higher is consumers' willingness to pay, the higher is the premium.

However, our model provides a counter-example to this claim and has the following implications:

- Mandatory disclosure *may* lead to different outcomes than voluntary disclosure. Mandatory disclosure may cause overall market prices to fall, as disclosure intensifies price competition. The more heterogeneous are consumers, the more prices will fall if an all-worse-off outcome realizes. Still, mandatory disclosure may as well cause overall market prices to rise, as disclosure alleviates price competition. The more heterogeneous are consumers, the more prices will rise if an all-better-off outcome realizes. This implication can be best tested if price data before/after a regime change (say, a law mandating disclosing quality information becomes in force) are collected.

[34] Say, mandatory disclosing laws are imposed in a market previously with credible voluntary disclosure mechanisms.

- In markets with imperfect competition, one firm's quality disclosing behavior may exert an "externality" effect on its rivals. Suppose we are looking at a market with credible accreditation system. Our model predicts that prices of unaccredited firms may rise if their rivals get accredited, since accreditation of some firms may alleviate price competition in the market. This prediction is clearly different from what the "unraveling result" predicts.

## 5. Conclusions

If the Grossman-Milgrom unraveling result is solid, one may wonder why industry associations are usually vehemently against government's imposition of mandatory disclosing laws about product quality.[35] As far as back in 1976, we saw NADA's (National Automobile Dealers Association) lobbying led to the abolishment of the FTC mandatory inspection and disclosure rule on the used-car dealers. As recent as 1998, we found the National Restaurant Association in a position strongly against the required public display of hygiene grade cards of all the restaurants in the Los Angeles County.[36] Questions arise, naturally: what are these associations worrying about, should mandatory disclosure makes no difference from voluntary disclosure, according to the "unraveling result"? Besides the all the claims made about the subjective standards of quality and high costs of information gathering, shall we suspect that what really behind the scene is lucrative motivation? Shall we suspect that mandatory disclosing laws bring consumers more information than what firms with private information will voluntarily supply? Shall we suspect that consumers' possession of quality information does firms harm instead of good in terms of profits? These are the central issues our paper has tried to explore.

[35] A noteworthy observation of similar nature is that some professions do not resist—and sometimes encourage—legal restrictions on advertising (Grossman and Shapiro, 1984; Peters, 1984).

[36] See: http://www.pioneerplanet.com/restaurantreservations/dayfive.htm. The National Restaurant Association states "rating initiatives reduce complex issues to a score or letter based on subjective decisions by individual inspectors." The industry maintains that if an establishment is good enough to pass inspection, ratings are overkill.

Taking into count consumer heterogeneity and firms' price-making behavior, we are able to show that:

- Consumer heterogeneity (along two dimensions) and firms strategic behavior will lead the "unravel result" to fail in some circumstances. This implies that government intervention (like mandatory disclosure rules) in markets with incomplete information may be beneficial for consumer welfare.
- The disclosure outcome is heavily influenced by consumer multidimensional heterogeneity. More informational flow in the market will bring market prices down, or up, depending on how consumers' multidimensional preferences are distributed. This result may have important empirical implications.

As we have discussed before, Grossman and Shapiro (1984) shows that advertising of firms' horizontal attributes (location) will raise the elasticity of individual demand and bring down market prices. We have shown this can also happen in the case of truthfully disclosing firms' vertical attribute—quality—when consumers who care about quality more horizontally prefer the low-quality product and those who care less horizontally prefer the high quality product. Our result is more general than Grossman and Shapiro result in the sense that our model allows for the contrary circumstances to arise: advertising/disclosing may as well result in a decrease of demand elasticity thus a universal increase of market prices. Leslie and Jin (2001) find that mandatory displays of hygiene quality cards in Los Angeles county bring revenue up for both A- and B- grade restaurants; slight decrease for C-grade ones. They also find voluntary displays bring revenue up for restaurants with all grades (the net effects for B-graded and C-graded are not significantly different from those for A-graded), though the magnitude of revenue increase is less than that under mandatory disclosure. This is not supported by the tradi-

tional “unraveling” view, which implies that high-quality firms gain from disclosure while low quality firms lose; neither is it supported by the ‘search-cost” view, which implies that market prices fall since consumers search costs become smaller. However, their empirical discovery can be supported by our model: both high-quality and low-quality firms may gain from disclosure since disclosure may alleviate price competition.

Finally, our research suggests, privately-informed firms’ decisions to reveal their quality, should be considered as an integrated part of firms’ positioning choice among an array of product attributes over which consumers have heterogeneous preferences. Nothing concerning firms’ proprietary information can be so readily “unraveling”: a firm producing a product with a high-quality attribute may or may not happily choose revelation over silence, depending whether it has or has not the necessary “niche.”

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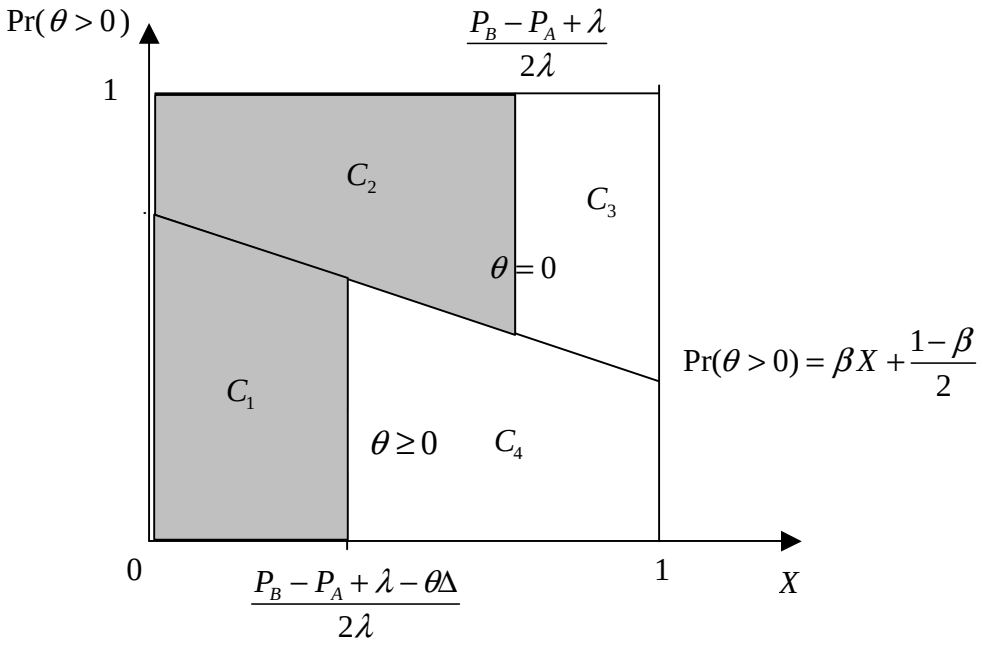
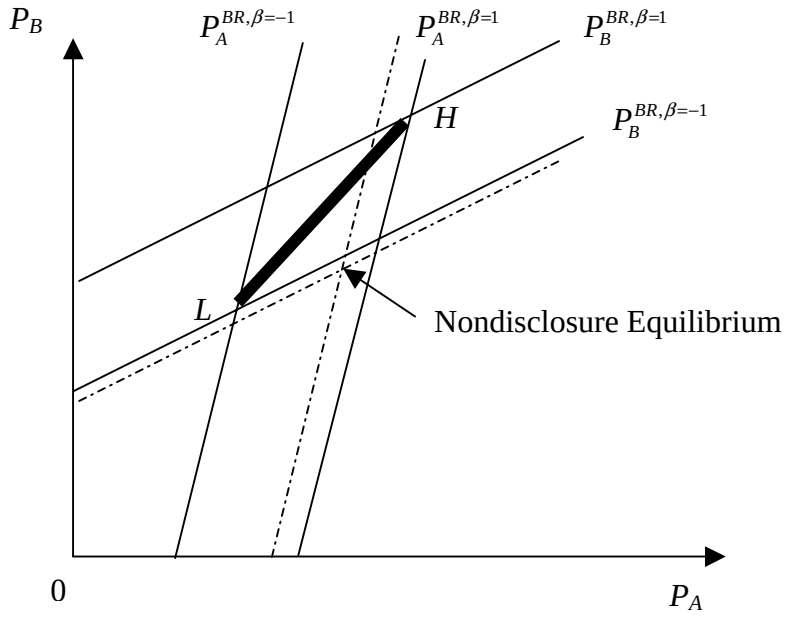
## Figure 1

**Consumer Purchasing Decisions and Firm Market Shares**
**When Product Quality is Disclosed and $\theta$ and $X$ are Negatively Correlated over Consumers**



## Figure 2

**Firms Best Response Functions and Disclosure and Non-Disclsoure Equilibria when $\theta$ and $X$ are Sufficiently Negatively Correlated**



# Appendix

## Re-Analyzing Findings about Voluntary Disclosure when Consumer Preferences over Quality are Continuous

In this appendix, we explore whether the above conclusions drawn about the incentives for voluntary disclosure are altered if we allow for a continuum of types of consumers with respect to preferences over quality.

From Figure 2, we saw that for the after-disclosure equilibrium to be in the southwest direction of the before-disclosure equilibrium, it requires the movements of best-response curves from the non-disclosure best-response curves are asymmetrical. The best-response curve of the low-quality firm needs to move downward by a greater magnitude than that of the high-quality firm moves upward. This will not happen unless there are certain relationships among consumers' multidimensional preferences. To better investigate these relationships in a continuous way, we set up a discrete-choice model of differentiated products and continuous consumer type.

Suppose there are two firms with both horizontal and vertical differentiation. The horizontal differentiation comes from their locations in a linear city: each firm is located in one end of the city. The distance between the two ends is 1 and consumers are indexed by $X$ and are uniformly distributed along the real line characterizing the linear city. Still, the firm at location 0 produces a product with low quality ($q_l$,) while the one at location 1 produces a product with high quality ($q_h$). If a consumer at location $X$ wants to buy the low-quality product, she has to incur a cost of $\lambda \log X$,[37] while if she wants to buy the high-quality product, she has to incur a cost of $\lambda \log(1-X)$. We assume that $X$ is uniformly distributed between 0 and 1. For simplicity, there is no outside option and consumers will either buy the low- or high-quality product.

In a unified market, the $i^{th}$ consumer's utility functions are specified as follows:

[37] We use log form here for computing convenience.

$$U_{iA} = V + \theta^i q_l - \lambda \log X_i - P_A$$
$$U_{iB} = V + \theta^i q_h - \lambda \log(1 - X_i) - P_B \tag{32}$$

A consumer will buy the low-quality product ($Y_A$) if and only if $U_{iA} > U_{iB}$, which implies: $\theta\Delta + \lambda \log \frac{X}{1-X} \leq P_B - P_A$. The advantage of this model is that there is no dichotomous distinction of two groups of consumers so we can better study how the relationship between $\theta$ and $X$ plays in the model. We study three cases:

1. $\theta$ and $X$ are independently distributed.
2. $\theta$ and $X$ are positively correlated.
3. $\theta$ and $X$ are negatively correlated.

Let $\theta = \overline{\theta} X^{\frac{1+\gamma}{2}} (1-X)^{\frac{1-\gamma}{2}}$, where $\alpha \in$ [-1,1] and $\overline{\theta}$ measures the spread of heterogeneity of consumers' quality preference.[38] As $\gamma$ ranges from -1 to 1, the correlation between $\theta$ and $X$ goes from being negative to being positive. In this model, a positive correlation between $\theta$ and $X$ means that consumers who prefer the product at location 0 tend to value quality less than those who prefer the product at location 1. And a negative correlation between $\theta$ and $X$ means that consumers who prefer the product at location 0 tend to value quality more than those who prefer the product at location 1. Independence between $\theta$ and $X$ means no above relationship exists.

For the above generalization of our model, the following conclusions about the pricing decisions and profits of firms when allowing either or both of the firms to voluntarily disclose their quality can be drawn. See Figure A-1. If the difference in the quality of the products of the two firms is not to big, then it follows that:

[38] We notice $\overline{\theta}$ shifts the mean of consumers' quality preferences at the same time. But the main effect of $\overline{\theta}$ should

1) When the positive correlation between $\theta$ and $X$ is big enough, disclosure leads to increased price levels and increased profits for both firms.
2) When the negative correlation between $\theta$ and $X$ is big enough, disclosure leads to decreased price levels and decreased profits for both firms.
3) When the correlation between $\theta$ and $X$ is in between the above two cases, disclosure leads the high-quality firm to gain and the low-quality firm to lose.

These conclusions are entirely consistent with our previous model. When the distribution of $\theta$ and $X$ across consumers are not systematically related, the firm selling the high-quality product gains an absolute advantage after disclosure. The demand for the high-quality product, $Y_B$, becomes less elastic while the demand for the low-quality product, $Y_A$, becomes more elastic, which results in increases in $P_B$ and declines in $P_A$ relative to the non-disclosure situation. When $\theta$ and $X$ are sufficiently positively correlated, the "home" market for the high-quality product is disproportionately made up of quality-lovers and, as a result, the "advantage" for the high-quality product, $Y_B$, is strengthened and its demand becomes less elastic. Likewise, the demand for the low-quality product, $Y_A$, becomes less elastic. As a result, both firms are able to raise their prices relative to the non-disclosure case.[39] When $\theta$ and $X$ are sufficiently negatively correlated, the "home" market for the high-quality firm is composed of quality-neutrals, thus the advantage of the high-quality product, $Y_B$, is weakened and its demand becomes more elastic. The same is true for the low-quality product, $Y_A$. As a result, the elasticities of demand for both products increase and, in equilibrium, results in both firms charging lower prices and realizing lower profits, relative to the non-disclosure case.

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be on the variances.

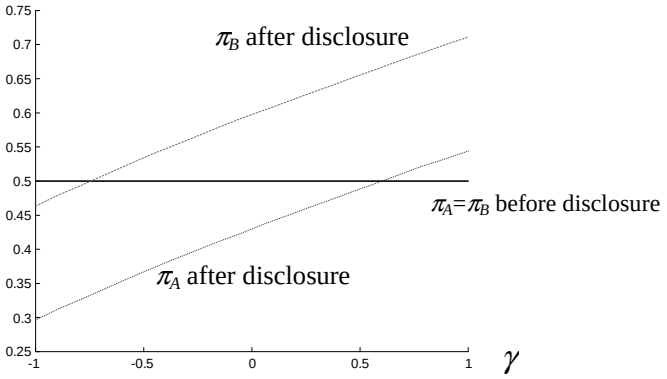
[39] A drawback of this model is that there is no outside option thus prices increase of both firms will bring profits up.

Figure A-2 illustrates how the prices and profits of the two firms under disclosure depend on the spread of heterogeneity of consumer preferences about quality. In particular, in the case where $X$ and $\theta$ are negatively distributed amongst consumers, the more consumers are differentiated in their taste for quality, the lower are the overall market price levels relative to the non-disclosure equilibrium.

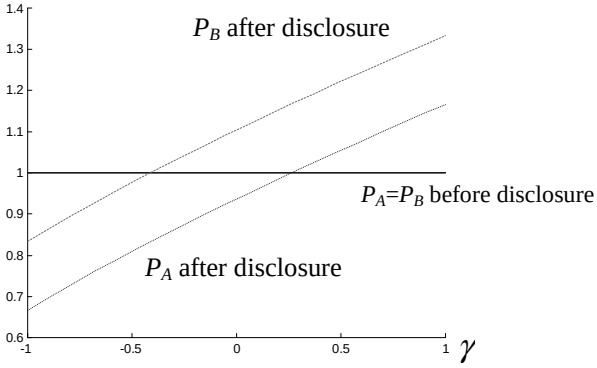
# Figure A-1

**Firm Profits, Prices and Market Shares Before and After Disclosure as $\gamma$, the Relationship between $\theta$ and $X$, Varies in the Continuous Preference Case**

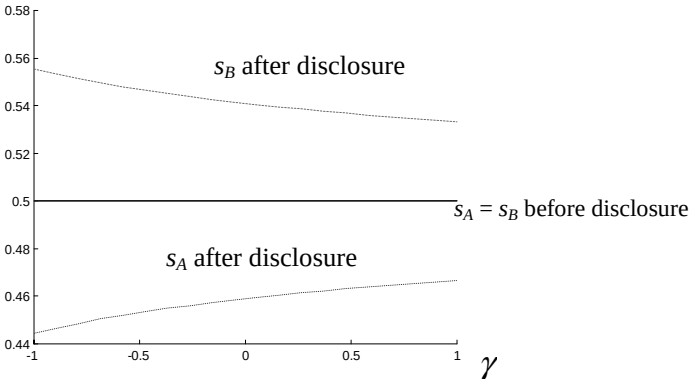
[Parameter Values Assumed: $\lambda = 1$; $\Delta = q_h - q_l = 0.5$]




Profits




Prices



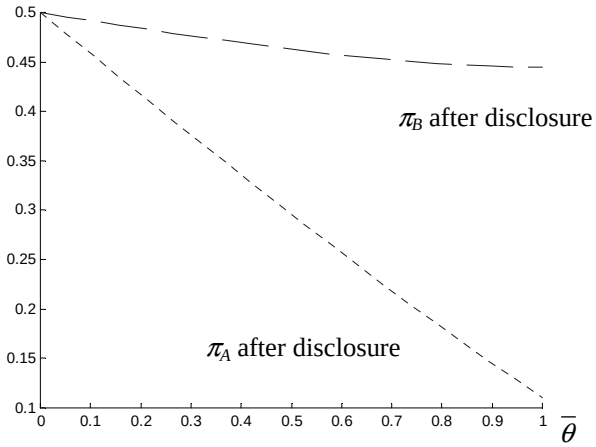

Market Shares

Note: $\gamma$ measures the relationship between the two dimensions of consumers' preferences.

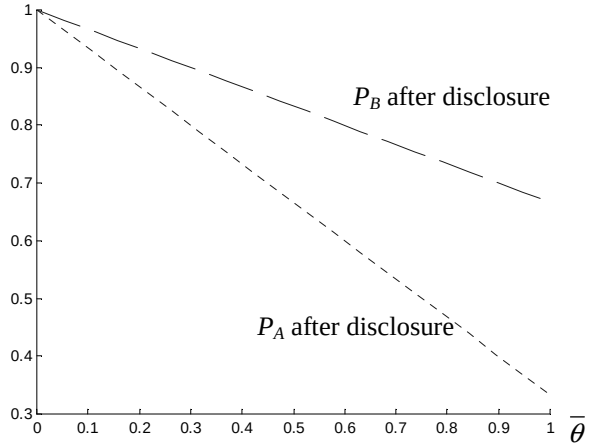
# Figure A-2

**Firm Profits, Prices and Market Shares Before and After Disclosure as $\bar{\theta}$, the Extent of Heterogeneity in Consumer Preferences over Quality, Varies in the Continuous Preference Case**

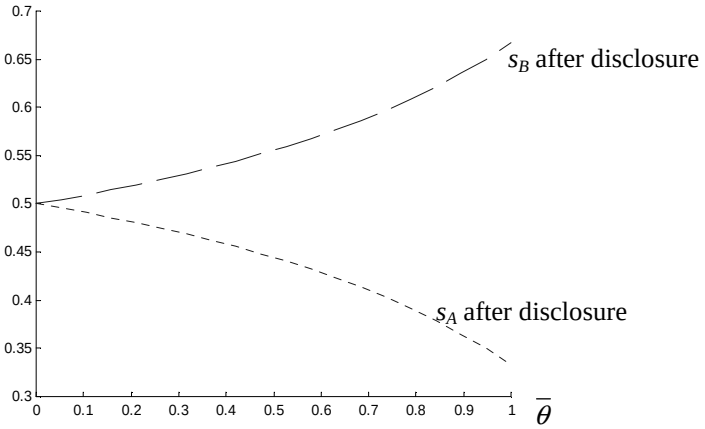
[Parameter Values Assumed: $\lambda = 1$; $\gamma = -1$; $\Delta = q_h - q_l = 1$]




Profits




Prices




Market Shares

Note: $\bar{\theta}$ measures the spread of heterogeneity of consumers' preferences for quality.