Product Quality, Reputation, and Market Structure*

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Abstract
In a repeated game in which firms simultaneously choose price and product quality, but quality is observed only after consumption takes place, equilibria exhibiting high quality may exist in oligopoly markets even when the low-quality is a unique equilibrium outcome in monopoly and competitive markets. Oligopolists can sustain high quality through the threat of both a loss of reputation and a breakdown in tacit collusion. While we abstract from other reasons that market structure might affect product quality, we show that the inverted-U shaped relationship between feasible quality and market structure is robust to several generalizations of the model.

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1 Introduction

The relationship between market structure and product quality is an important and widely studied part of the theoretical industrial organization literature going back to Schumpeter’s (1943) work on the relationship between innovation and market structure and including the seminal work of Swan (1972) on market power and product durability. We contribute to a small, but important, insight to this debate, by asking how market structure influences the incentives to provide high quality product when quality is unobservable, that is, when the products sold are experience goods, and when firms can tacitly collude. Theoretically, higher margins give stronger incentives to sustain a reputation for a high quality, and they encourage firms to increase product quality in order to steal business from rivals. This is also true empirically. In the airline industry, deregulation lead to lower prices and a reduction in service quality.\footnote{Graham, et. al, (1983) show that the frequency of departures declined following deregulation.} On the other hand, competition encourages firms to protect their market share by competing in product quality. In general, monopolists have higher margins but face less of a threat from competition, while firms in competitive markets have lower margins and face a greater threat from competition. In between are the oligopoly markets. Firms in oligopoly markets may enjoy high margins (because of tacit collusion) and face a strong threat from competition, which suggests product quality might be highest in imperfectly competitive markets. This paper considers a repeated game model of pricing and product quality choice in which market structure has a nonmonotone impact on firms’ ability to maintain reputation for high quality; high quality is more likely to be an equilibrium in oligopoly markets than in either monopoly or competitive markets.

Empirical evidence on the relationship between market structure and quality is mixed. Mazzeo (2003) finds that on-time performance increases dramatically when a second non-stop carrier serves a route. Domberger and Sherr (1989) find that the British government’s liberalization of the conveyancing monopoly in 1984 led to improvement in quality of conveyancing services in England and Wales. These papers are consistent with our model in that they emphasize some competition increases quality relative to monopoly. Another empirical paper, McMaster (1995), finds that introducing competitive bidding for some health services in the United Kingdom led to lower quality of these services. This is consistent with our prediction that within an oligopoly market, quality should fall as the number of firms rises, or more generally, as tacit collusion becomes more difficult.

We consider an oligopoly model in which firms sell experience goods, that is goods whose quality is unobserved until after the purchase decision. High quality can be
sustained more easily by oligopoly firms than by either a monopoly firm or by firms in a competitive market. More precisely, we consider a model in which firms can choose either to sell a high quality or low quality good and find that a high quality good can be supported as a perfect Bayesian equilibrium outcome for a larger range of discount factors in an oligopoly market.

The intuition for our result can be seen by considering the analogous problem in which experience-good sellers each sell two products, a primary product with observable quality and a secondary upgrade with unobservable quality. The upgrade is either high or low quality and the value of the upgrade to consumers is zero when the quality is low. Now imagine that the firms produce and sell only the upgrade. If a price exists at which a monopolist can sustain a reputation for a high quality upgrade, it follows that firms in an oligopoly and competitive markets can sustain a reputation for a high quality upgrade at the same price. This is because quality can be sustained by giving each firm a fixed share of the market and having consumers punish each firm with zero sales and zero profits if it ever produced low quality, so the ability to sustain a reputation for high quality upgrade is independent of market structure.

Now suppose instead that firms produce and sell both the primary product and the upgrade. A monopolist earns its monopoly profit from the primary good, and firms in a competitive market earn zero profit from the primary good, and these profits are independent of whether or not the firms sell a high-quality or a low-quality upgrade. In contrast, the profit that firms in an oligopoly earn on the primary product can be anything ranging from the competitive profit to the monopoly profit; the profit depends on the discount factor and on the firms’ equilibrium strategies. This means that oligopolists using history-dependent strategies can tie the profits they earn on the primary product to their reputations for selling a high quality upgrade. The ability of firms to punish each other through a reduction in the price of the primary product means that the punishment for a deviation in the product quality is larger and the firms have a stronger incentive to produce high quality.

Since higher quality may only be feasible when the market is sufficiently concentrated our theory also suggests a potential social benefit from imperfect competition. Despite this social benefit from market concentration, we find that for a wide range of parameter values for which both low quality and high quality equilibria exist, consumers strictly prefer any low quality equilibrium to all of the high quality equilibria.

\[2\] Making an analogy between selling a primary product of known quality and a upgrade of unknown quality and selling a single product of unknown quality also requires that we assume that the upgrade can only be sold when it is bundled with the primary product. However, our intuition is valid whether or not we make this assumption.
The paper is organized as follows. In Section 2 we discuss the related literature. In Section 3 we describe the basic model and the solution for the monopoly and competitive environments. In Section 4 we characterize the perfect Bayesian equilibrium for oligopoly and show that high quality is easiest to sustain in the duopoly market structure. Section 5 contains welfare analysis. Section 6 considers the robustness of our analysis to alternative modeling assumptions. Most importantly, we emphasize that our results are robust to the introduction of product differentiation, and also emphasize that product differentiation and the number of firms are fundamentally different measures of competition, particularly in repeated game contexts. Finally, we find that high product quality is easiest to sustain when the market is less competitive, in the sense that the number of firms is small \((n = 2)\) and in the sense that the products are more highly differentiated.

2 Related Literature

The theoretical literature on the relationship between market structure and product quality is extensive, though much of it focuses on innovation. This is true of Schumpeter (1943) and many others, including the recent work by Aghion, et al. (2005). In this literature some degree of market power is necessary to give firms an incentive to undertake investments in innovation, though, as Aghion, et al. show, the market structure which provides the greatest incentives for innovation may be an intermediate one, and need not be monopoly.

Even in the absence of fixed costs of product development, market structure influences product quality. Swan (1970, 1972) characterized conditions under which competitive and monopoly markets introduced the same quality products and, in the special case of durability, introduced products with the same durability (this is often referred to as the Swan independence result). There are, however, important exceptions to this result. Most importantly, when customers have heterogeneous preferences over product quality then monopolists can have stronger or weaker incentives to increase quality than competitive markets (see for example, Waldman, 1996 and Hendel and Lizzeri, 1999, and earlier research by Gal-Or, 1983).

Because our paper focuses on repeated games and imperfect information about product quality, it is at the intersection of two literatures: the literature of reputations for product quality and the literature on tacit collusion.\(^3\)

\(^3\)An excellent survey of the tacit collusion literature, written largely for policy makers, is Ivaldi, et al. (2003). An excellent early survey of the reputation literature is Stiglitz (1989). Mailath and Samuelson (2006) survey the more recent contributions to this literature.
Klein and Leffler (1981) and Shapiro (1983) consider models in which reputations are a mechanism to support high quality in a repeated moral hazard model. They showed that for any discount factor there exists a minimum price premium (and equivalently for any price premium, a minimum discount factor) required for high quality to be sustainable. Comparing the required price premium with consumers’ willingness to pay for a high quality product determines the minimum discount factor needed to sustain high quality.

As Stiglitz (1989) observes, the existence of a price premium implies that firms must earn positive profits and that competition may place limits on the level of quality that can be supported. In this spirit, Kranton (2003) shows that competition may cause firms to bid the market price down to a level that high quality cannot be supported as a subgame perfect Nash equilibrium outcome. However, Kranton considers only equilibria in which consumers’ beliefs about a firm’s quality depend only on the firm’s past quality and not on the firm’s prices.

Two other papers also look at the relationship between market structure and product quality in a repeated game. Under a similar restriction on consumer beliefs, Bar-Isaac (2005) provides an example in which there is a non-monotone relationship between competition and quality with a pattern that is opposite to ours. In his example, reputation for high quality is the hardest to sustain under intermediate level of competition. And Hörner (2002) shows that competition promotes quality when quality is noisily observed because it allows dissatisfied consumers to easily and credibly punish any firm by switching suppliers whenever it fails to produce high quality.

In a related paper, Calzolari and Spagnolo (2006) show that a buyer may choose to facilitate collusion among sellers in order to sustain higher nonverifiable quality. However, there are important differences in our papers. Most obviously, they analyze collusion among suppliers in repeated procurement auctions, and they model collusion as a form of bid rotation (so the buyer purchases from a single seller each period) while we assume that consumers divide their purchases evenly among the tacitly colluding sellers. However, the most substantive difference is that the buyer in their model is strategic and acts to exclude deviating sellers from future auctions, and because the buyer can replace deviating sellers with new suppliers, the highest sustainable quality is achieved when the buyer allows just one seller to participate in the auction (maximizing the sellers market power rents on the equilibrium path) and then exercises its credible threat to exclude and replace the seller if it ever deviates

\[\text{In Bar-Isaac (2005), firms choose quantity and quality instead of price and quality. His assumption that consumers do not infer quality change from change in quantity is in the same spirit of Kranton’s assumption.}\]
in quality. As a consequence, their paper does not find that tacitly colluding firms in oligopoly markets can sustain higher quality than a monopolist while ours does.

Other than Calzolari and Spagnolo (2006) and our paper, the literature has not studied tacit collusion among experience good sellers. Within the tacit collusion literature our work is most closely related to Bernheim and Whinston’s (1990) work on multimarket contact. They show that competing in multiple markets can facilitate tacit collusion, but only when the markets are asymmetric. In our paper, we argue that it can be easier for firms to simultaneously tacitly collude on prices and maintain reputations of high product quality than to do either of these activities alone. These two activities are naturally asymmetric, so in that sense, our insights are consistent with Bernheim and Whinston’s observation that increasing the dimensions of contact between the firms can increase profitability.

In a similar way our work is also related to repeated moral hazard models in the literature on brand extensions. Several papers (including Montgomery and Wernerfelt, 1992, Wernerfelt, 1988, Choi, 1998, Cabral, 2003, and Andersson, 2002) show that it can be easier for a monopolist to maintain a reputation for high quality when using a single umbrella brand on multiple products rather than using a single brand on each product. This literature has generally not looked at the impact of competition on the incentives for brand extensions.

3 The Model

The model is a repeated game in which \( n \geq 1 \) symmetric, infinitely-lived firms sell to a unit mass of homogeneous consumers. Each consumer has valuation \( v_h \) for a single unit of a high quality good. Each consumer has valuation \( v_l < v_h \) for a single unit of a low quality good.

Each period every firm simultaneously chooses its product quality, either \( q_l \) or \( q_h \), and its price, \( p \), both of which are constrained to be the same across all the consumers. Consumers then choose whether or not to consume and from which firm to purchase.

Consumers observe prices before they make their purchase decisions, but they

\footnote{Dana and Fong (2006) show that firms offering multi-period subscription contracts can endogenously create multimarket contact. Although these markets are symmetric, tacit collusion still becomes easier because these markets take turn to open sequentially.}

\footnote{In a related paper, Dana and Spier (2006) show that product bundling helps firms to maintain a reputation for high quality when consumers are small, have heterogeneous preferences, and privately observe product quality. In their model, consumers will free ride and not punish optimally unless products are bundled.}
do not observe firms’ product quality decisions until after making their purchase decision. We assume perfect monitoring ex post, that is, we assume that firms’ price and product quality decisions become common knowledge to all consumers and firms at the start of the next period.

Production exhibits constant returns to scale. Each unit of the high quality product costs $c_h$ to produce and each unit of the low quality product costs $c_l$ to produce, where $c_l < c_h$. We assume $v_l > c_l$, so equilibrium sales are strictly positive even if consumers believe that only the low quality product is supplied. We also assume that a social planner would produce only the high quality good. In other words, we assume that $v_h - c_h > v_l - c_l$.

The common discount factor is $\delta \in [0, 1]$.

Throughout the paper we focus on stationary, symmetric perfect Bayesian equilibria. Consumers’ purchase decisions are a function of firms’ current prices and their beliefs about firms’ current product qualities which are a function of firms’ past actions, and consumers’ beliefs are consistent with Bayes’ rule and firms’ equilibrium strategies.

Before solving the general model, we consider two important benchmarks.

**Benchmark 1: Competition and Unobservable Quality**

Suppose that quality is unobservable, but that the number of firms is very large. Clearly this implies tacit collusion is impossible. However, it may nevertheless be possible to support the provision of a high quality product in equilibrium. As long as firms make positive profits and consumers punish firms that shirk on quality by purchasing from different firms in the future, high quality can be supported if firms are sufficiently patient.

Consider the following equilibrium strategies. On the equilibrium path, every firm produces high quality and charges a price $p$ every period. Consumers expect high quality as long as the firm’s price is $p$ or higher. Off the equilibrium path, consumers expect each firm to offer low quality if 1) that firm announces a price below $p$, or 2) that firm has offered either a lower price or a low quality product in the past. In other words, if a firm deviates in either price or quality, then in all future periods, consumers expect that firm to offer low quality. Following any deviation, every other firm continues to play their static Nash strategies.

![Equation Image]

Note that when the number of firms selling high quality is very large, it follows that $v_h - p \geq v_l - c_l$ or $p \leq v_h - v_l + c_l$. Otherwise a firm could offer a price greater than $v_h - c_h$ without losing sales to competitors. The equilibrium can also be supported by assuming that following any deviation every other firm could continue to play their equilibrium strategies.
than $c_l$ and capture the entire demand even when consumers expect this firm to produce low quality.

Also, note that since $p \leq v_h - v_l + c_l$, if a firm shirks on quality, its profits are nonpositive every period thereafter. It cannot profitably sell a low quality good. So an equilibrium in which firms produce high quality products exists using the above strategies if and only if

\[
\frac{p - c_h}{1 - \delta} \geq p - c_l + 0
\]

for some price $p \leq v_h - v_l + c_l$.

This implies:

**Lemma 1 Competitive Reputation (Klein-Leffler, 1981, Shapiro, 1983, Allen, 1984):** When quality is unobservable and there are a continuum of firms, there exists a perfect Bayesian equilibrium in which firms offer high quality if and only if there exists a price $p \leq v_h - v_l + c_l$ such that (1) holds, or equivalently, if and only if

\[
\delta \geq \delta_0^Q = \frac{c_h - c_l}{v_h - v_l}.
\]

**Benchmark 2: Monopoly and Unobservable Quality**

Next consider a monopolist ($n = 1$) who sells a product each period whose quality is unobservable. Or equivalently, consider the case in which the $n$ firms each have monopoly power over a fraction $1/n$ of the consumers.

In the unique Nash equilibrium of the single-period stage game each firm sells a low quality product at a price $v_l$. This behavior is also an equilibrium of the infinitely repeated game. However, in the infinitely repeated game a monopolist may be able to support higher quality in a perfect Bayesian equilibrium using the threat of static Nash reversion.

Specifically, suppose consumers’ equilibrium expectations are that the firm will produce high quality as long as the price is $p$ or higher and the firm has only produced high quality and priced at $p$ or above in the past, but they expect low quality forever whenever the price is below $p$ or they observed the firm produce low quality in the past. These represent consumers’ optimal punishment strategies.

Given these off-the-equilibrium-path strategies, high quality can be supported in a perfect Bayesian equilibrium as long as the present discounted value of all future profit on the equilibrium path exceeds the profit associated with shirking on quality.
and thereafter selling a low quality product at a price of $v_l$. The present discounted value of all future profits on the equilibrium path must also exceed the profit associated with a deviation in price or a deviation in both price and quality. However, since consumers expect low quality immediately after seeing a price deviation, the payoff from any other deviation is no higher, and in most cases strictly lower, than the payoff from deviating in quality alone.

So, for a given price $p$, high quality can be supported as a perfect Bayesian equilibrium if and only if

$$\frac{p - c_h}{1 - \delta} \geq (p - c_l) + \delta \frac{v_l - c_l}{1 - \delta}.$$  

It follows that for a given price, high quality can be supported as a prefect Bayesian equilibrium for all

$$\delta \geq \frac{c_h - c_l}{p - v_l}.$$  

Moreover, since the critical value is decreasing in $p$, it follows that if high quality can be supported at any price, it must be supportable at $p = v_h$. This implies:

**Lemma 2 Monopoly Reputation:** When a single firm sells a product with unobservable quality, if

$$\delta \geq \delta^Q_0 = \frac{c_h - c_l}{v_h - v_l},$$

then perfect Bayesian equilibria exist in which the firm produces high quality, and otherwise the unique equilibrium outcome is low quality at a price of $v_l$.

This implies the following corollary:

**Corollary 3 Independence:** High quality can be supported as a perfect Bayesian equilibrium outcome by firms in a competitive market if and only if high quality can be supported as a perfect Bayesian equilibrium outcome by a monopolist.

Corollary 3 is a repeated-game analogy to Swan’s independence result for observable quality. Recall that Swan (1970, 1972) derived conditions under which equilibrium product quality (or durability) was independent of whether the market was competitive or operated by a monopolist.

An intuitive way to see Corollary 3 holds is to think of the firms as selling two goods, a primary good of low quality and a secondary upgrade, where the upgrade
can increase the quality from low to high. First suppose quality is observable and so
the upgrade is always a genuine upgrade. The value of the primary good is $v_l$ to all
consumers, and its cost is $c_l$. The high quality upgrade is worth $v_h - v_l$ and costs the
firm $c_h - c_l$. For both a monopolist and a competitive firm, the profit earned from
the primary product is independent of the price that the firm charges for the upgrade (in
the case of a monopolist, the profit earned on the primary product is the monopoly
profit and in the case of competitive firms that profit is zero). So regardless of the
market structure, firms sell the upgrade if $v_h - v_l > c_h - c_l$. Provision of the upgrade
(and hence overall product quality of the firm) is independent of market structure.

The independence result continues to hold when the quality of the upgrade is
unobservable. Now the upgrade either has value 0 to consumers and cost 0, or it
is worth $v_h - v_l$ and costs the firm $c_h - c_l$, depending on whether the firm chooses
to sell a genuine upgrade. Again, the profit on the primary good (which is known
to be the basic, low quality good, is independent of the upgrade price. Also, note
that, given the same market price, the monopolist and competitive firms make the
same tradeoff in deciding the quality of upgrade. A firm shirking on quality upgrade
saves $c_h - c_l$ for each unit of its market share and loses its share of all the future
profits. Therefore, if there exists no price at which the monopolist can sustain a
reputation for a high quality upgrade than there exists no price at which competitive
firms can do so. And similarly, if there does exist a price at which the monopolist can
sustain a reputation for a high quality upgrade, then there must also exist a price at
which competitive firms can do so. That is, both types of firm are able to sustain a
reputation for a high quality upgrade if and only if the present value of the profits
earned on producing the genuine upgrade exceeds the one shot profit from selling a
inferior upgrade, that is, if

$$
\frac{(v_h - v_l) - (c_h - c_l)}{1 - \delta} \geq v_h - v_l,
$$

or $\delta \geq \delta^Q_0$.

The crucial assumption is that consumers are homogeneous. It is easy to see that
relaxing this assumption could make quality either harder or easier to sustain for a
monopolist. In particular, suppose a small measure of additional consumers had a
zero valuation for the low quality good and valuation $v_h$ for the high quality good.
In this case, when the monopolist loses its reputation, it loses not just the revenue
stream $(v_h - c_h) - (v_l - c_l)$ from each of the main consumers, but also $v_l - c_l$ from each
of the additional customers, so the monopolist has a greater incentive to continue to
offer high quality (the range of $\delta$ that support high quality is larger). However, the
incentives to offer high quality for competitive firms are unaffected. On the other hand, suppose a small number of additional consumers had valuation \( v_h - v_l + c_l \) for the high quality good and a zero valuation for the low quality good. The existence of these additional consumers increases the competitive firms’ equilibrium profit without increasing their deviation profit (because these additional consumers place no value on the low quality good), so high quality is easier to sustain in competitive markets. But at a price of \( p = v_h \), the monopolist’s incentive to offer high quality is unchanged (since these consumers do not buy the good) and in any lower price equilibrium in which these consumers do buy the good, the monopolist’s equilibrium path profits must still be lower as long as there are sufficiently few of these additional consumers. So in this case it is easier for competitive firms to sustain high quality than a monopolist.

4 Oligopoly and Unobservable Quality

We now consider the general model. First, notice that selling low quality at a price of \( c_l \) is the unique Nash equilibrium of the one-shot game. This is because offering low quality is a dominant strategy and Bertrand price competition among homogeneous firms leads to marginal cost pricing. So it follows that selling low quality at a price of \( c_l \) in every period is also an equilibrium of the repeated game.

Now, consider the following equilibrium strategies in which firms punish rivals’ deviations. On the equilibrium path, firms produce high quality and sell at price \( p \) every period. Consumers expect high quality and \( \frac{1}{n} \) of them purchase from each firm as long as \( v_h \geq p \). Off the equilibrium path, if any firm deviates in either price or quality, then in all future periods, all firms revert to the static Nash equilibrium selling low quality at a price of \( c_l \) and earn zero profits. Consumers have rational expectations, so all consumers and firms expect a firm to offer low quality if any firm has offered either a lower price or a low quality product in the past. In addition, consumers expect a firm to offer low quality in the current period whenever that firm announces a price below \( p \). This belief is fully consistent with firms’ subsequent off-the-equilibrium path behavior. When a firm deviates in price, it anticipates zero profit in all future periods regardless of its current quality. Hence, a firm that deviates in price has no incentive to produce high quality in the current period. Also note that these are the optimal punishments. It is impossible to impose negative profits on the deviator, so these strategies impose the most severe punishment and hence characterize the highest sustainable quality.

Consider the firm’s incentive to shirk on quality. Given these strategies, the firm
will not shirk on quality as long as
\[
\frac{p - c_h}{1 - \delta} \geq p - c_l.
\]

Let $\delta^Q(p)$ be defined as the value of $\delta$ for which this constraint holds with equality. So (7) is satisfied as long as
\[
\delta \geq \delta^Q(p) \equiv \frac{c_h - c_l}{p - c_l},
\]
or equivalently
\[
p \geq \frac{c_h - (1 - \delta) c_l}{\delta}.
\]

Clearly $\delta^Q(p)$ is decreasing in $p$, so supporting high quality is easier at higher prices.

Next consider the firm’s incentive to lower price. A firm that deviates in price is expected to produce low quality, so clearly it will produce low quality. Conditional on deviating, the firm will maximize its deviation profit, which is
\[
\Pi_l(p', p) = \begin{cases} 
p' - c_l & \text{if } v_l - p' \geq v_h - p, \\
0 & \text{otherwise},
\end{cases}
\]
where $p'$ is the deviating firm’s price. It follows that the most profitable deviation is $p' = p - (v_h - v_l)$ if $p - (v_h - v_l) > c_l$ and $p' = c_l$ otherwise. So if $p \leq v_h - v_l + c_l$ the firm has no incentive to deviate in price. If $p > v_h - v_l + c_l$, then the firm has no incentive to deviate in price as long as
\[
\frac{1}{n} \frac{(p - c_h)}{(1 - \delta)} \geq p - (v_h - v_l) - c_l,
\]
or equivalently
\[
\delta \geq \delta^P(p, n) \equiv 1 - \frac{1}{n} \frac{(p - c_h)}{(p - (v_h - v_l) - c_l)}.
\]

If consumers did not infer low quality from price cut, as modeled in Kranton (2003), then the deviation profit would have been $p - c_l$ and the incentive constraint would have been
\[
\frac{1}{n} \frac{(p - c_h)}{(1 - \delta)} \geq p - c_l.
\]

In this case, the incentive constraint would necessarily fail for sufficiently large $n$. In our analysis, given that firms reverts to low quality and marginal cost pricing following any deviation, no rational consumer will believe that a firm which deviates in price will produce high quality.
This condition can be satisfied if and only if there exists $p \leq v_h$ such that

$$p \leq \frac{(1 - \delta) n((v_h - v_l) + c_l) - c_h}{(1 - \delta) n - 1}.$$  

Finally note that we do not need to separately consider deviations in both price and quality. Since a firm that deviates in price always chooses low quality, our analysis of the firm’s optimal price deviation is sufficient.

This can be summarized as follows:

**Lemma 4** For any finite number of firms, $n > 1$, high quality and the price $p \in (c_h, v_h - v_l + c_l]$ can be supported as a perfect Bayesian equilibrium outcome if and only if $\delta \geq \delta^Q(p)$. For any finite number of firms, $n > 1$, high quality and the price $p \in (v_h - v_l + c_l, v_h]$ can be supported as a perfect Bayesian equilibrium outcome if and only if $\delta \geq \delta^P(p, n)$ and $\delta \geq \delta^Q(p)$ are both satisfied.

Lemma (4) characterizes the set of $p$, $n$, and $\delta$ for which high quality is sustainable as a perfect Bayesian equilibrium outcome. The following proposition characterizes the set of $n$ and $\delta$ for which high quality is sustainable as a perfect Bayesian equilibrium outcome at some price and specifies the upper and lower bounds of the associated prices.

**Proposition 1** For any finite number of firms, $n > 1$, high quality can be supported as a perfect Bayesian equilibrium outcome if and only if

$$\delta \geq \min_{p \in (v_h - v_l + c_l, v_h]} \max \{\delta^Q(p), \delta^P(p, n)\}.$$  

or equivalently

$$\delta \geq \begin{cases} \frac{c_h - c_l}{v_h - v_l} & \text{if } n < \frac{v_h - c_l}{v_l - c_l}, \\ \frac{c_h - c_l}{v_h - v_l (1 - \frac{1}{n})} & \text{if } n \geq \frac{v_h - c_l}{v_l - c_l}. \end{cases}$$

The supportable equilibrium prices are

$$p \in \left[\frac{c_h - (1 - \delta) c_l}{\delta}, \min \left\{\frac{(1 - \delta) n((v_h - v_l) + c_l) - c_h}{(1 - \delta) n - 1}, v_h\right\}\right].$$

**Proof:** It follows immediately from Lemma 5 that for any finite number of firms, $n > 1$, there exists a price $p \in (v_h - v_l + c_l, v_h]$ such that high quality and the price $p$ can be supported as a perfect Bayesian Nash equilibrium if and only if
\[
\delta \geq \min_{p \in (v_h - v_l + c_l, v_h]} \max \{\delta Q(p), \delta P(p,n)\}.
\]

Both \(\delta P(p,n)\) and \(\delta Q(p)\) are continuous on \((v_h - v_l + c_l, v_h]\), and

\[
\frac{d\delta Q(p)}{dp} = \frac{c_h - c_l}{(p - c_l)^2} < 0,
\]

and

\[
\frac{d\delta P(p,n)}{dp} = \frac{(v_h - v_l) - (c_h - c_l)}{n (p - c_l - v_h + v_l)^2} > 0,
\]

so \(\delta Q(p)\) is everywhere decreasing in \(p\) and \(\delta P(p,n)\) is everywhere increasing in \(p\).

Also, near the lower bound of the interval \((v_h - v_l + c_l, v_h]\), \(\delta P(p,n) < 0\) and \(\delta Q(p) > 0\), so clearly \(\delta Q(p) > \delta P(p,n)\).

Note that \(\delta P(v_h, n) \leq \delta Q(v_h)\) if and only if

\[
\frac{c_h - c_l}{v_h - c_l} \leq 1 - \frac{1}{n} \frac{v_h - c_h}{v_l - c_l}
\]

or

\[
n \geq \frac{v_h - c_l}{v_l - c_l}.
\]

Suppose that \(\delta Q(v_h) \leq \delta P(v_h, n)\), or equivalently, \(n \geq \frac{v_h - \delta Q}{v_l - c_l}\), so that the two functions cross somewhere in the interval \((v_h - v_l + c_l, v_h]\). It follows that \(\max \{\delta Q(p), \delta P(p,n)\}\) is minimized at the intersection. Let \(\hat{p}(n)\) denote the price at which the two functions cross, so added the left and right most equalities

\[
\delta Q(\hat{p}(n)) = \frac{c_h - c_l}{\hat{p}(n) - c_l} = 1 - \frac{1}{n} \frac{(\hat{p}(n) - c_h)}{(\hat{p}(n) - (v_h - v_l) - c_l)} = \delta P(\hat{p}(n), n),
\]

or

\[
\hat{p}(n) = \frac{n}{n - 1} (v_h - v_l) + c_l.
\]

So

\[
\min_{p \in (v_h - v_l + c_l, v_h]} \max \{\delta Q(p), \delta P(p,n)\} = \delta Q(\hat{p}(n)) = \delta P(\hat{p}(n), n)
\]

\[
= \frac{c_h - c_l}{n - 1 (v_h - v_l) + c_l - c_l}
\]

\[
= \frac{c_h - c_l}{v_h - v_l} \left(1 - \frac{1}{n}\right).
\]
Now suppose that $\delta^Q(v_h) > \delta^P(v_h, n)$ so $n < \frac{v_h - c_l}{v_l - c_l}$. In this case

$$\min_{p \in (v_h - v_l + c_l, v_h]} \max \{ \delta^Q(p) , \delta^P(p, n) \} = \delta^Q(v_h) = \frac{c_h - c_l}{v_h - c_l}.$$ 

The lower bound on $p$ follows (9) and the upper bound on $p$ follows (12) and $p \leq v_h$. This completes the proof.

From the proof of Proposition 1, it is clear that raising $p$ improves the incentive to exert high effort and worsens the incentives to charge the equilibrium price. Therefore, the price that sustains the reputation for high quality for the largest range of discount factor is at some intermediate level, balancing these two incentives. This is in contrast to analyses in which tacit collusion in not considered. If we ignore the incentive to deviate in price, then it is always optimal to set the highest possible price so that in equilibrium a firm has the most to lose when it shirks on quality.

The solid line in Figure 1 shows the threshold value of $\delta$, defined in (13). For all $\delta$ above this threshold, production of the high quality product is sustainable. As we can see from the figure and equation (14), the threshold value of $\delta$ is constant for $n \leq \frac{v_h - c_l}{v_l - c_l}$, but for $n > \frac{v_h - c_l}{v_l - c_l}$, the threshold value of $\delta$ increases with the $n$. This is because $\frac{c_h - c_l}{v_h - v_l} \left( 1 - \frac{1}{n} \right)$ increases in $n$.

For comparison, Figure 1 also shows $\delta^Q_0$, which is the common critical threshold discount factor in the two benchmark models. The curve $1 - \frac{1}{n}$ is the critical threshold discount factor for tacit collusion when the product quality is commonly known. This curve will be used later for establishing Proposition 3.

We now show that an oligopoly with $n > 1$ firms can more easily sustain high quality then a monopolist.

**Proposition 2** For any finite number of firms, $n > 1$, the range of $\delta$ for which high quality can be supported with unobservable quality is strictly greater than the range of $\delta$ for which high quality can be supported under monopoly or competition with unobservable quality. Specifically, 

$$\min_{p \in (v_h - v_l + c_l, v_h]} \max \{ \delta^Q(p) , \delta^P(p, n) \} < \delta^Q_0$$

**Proof:** Since 

$$\delta^Q_0 = \frac{c_h - c_l}{v_h - v_l},$$

and since 

$$\frac{c_h - c_l}{v_h - v_l} > \frac{c_h - c_l}{v_h - c_l},$$ 

(18)
Figure 1: Comparison of critical values of $\delta$

and

\[
\frac{c_h - c_l}{v_h - v_l} > \frac{c_h - c_l}{v_h - v_l} \left(1 - \frac{1}{n}\right),
\]

equation (17) follows immediately from Proposition 1. ■

Proposition 2 establishes that for any $n > 1$, there exists a range of discount factors such that high quality can be sustained when a finite number of firms compete with one another, but high quality cannot be sustained when a single firm produces or arbitrarily many firms compete with one another. From (5) and (14), we can see that the range of discount factors for which high quality can be sustained in an oligopoly, but not in a monopoly, is $\left[\frac{c_h - c_l}{v_h - v_l}, \frac{c_h - c_l}{v_h - v_l} (1 - \frac{1}{n})\right]$ when the oligopoly is small, i.e., $n \leq \frac{v_h - c_l}{v_h - c_l}$, and $\left[\frac{c_h - c_l}{v_h - v_l}, \frac{c_h - c_l}{v_h - v_l} (1 - \frac{1}{n})\right)$ when the oligopoly is large, i.e., $n > \frac{v_h - c_l}{v_h - c_l}$. From (5) and (14), we can also see that for $\delta$ sufficiently small, i.e., $\delta < \frac{c_h - c_l}{v_h - c_l}$, high quality cannot be supported in any market structure. When $\delta$ is in an intermediate range, i.e., $\delta \in \left[\frac{c_h - c_l}{v_h - c_l}, \frac{c_h - c_l}{v_h - v_l}\right)$, then high quality can be supported only in an oligopoly of sufficiently small size. And finally, when $\delta$ is sufficiently large, i.e., $\delta \in \left[\frac{c_h - c_l}{v_h - v_l}, 1\right)$, high quality can be supported for any market structure.

Proposition 2 implies that the range of $\delta$ for which high quality can be supported is always highest for a duopoly. However, note that duopoly only strictly dominates
other market structures under some conditions. As Figure 1 clearly shows, sometimes duopoly sustains high-quality production equally well as other concentrated oligopolies. Also, our analysis abstracts from other forces that may affect the quality provision under different market structures. Once we include forces that drive competition to favor quality provision, the market structure that optimally sustain high quality may be an oligopoly with more than two firms. We consider generalizations of our model that change the ideal market structure for sustaining quality below in Section 6 of the paper.

Thinking of the firms as selling a primary good and a secondary upgrade also helps understand the intuition for Proposition 2. In Corollary 4 we saw that local monopolists and competitive firms have the same incentive to sustain a reputation for a high quality upgrade because in both the monopoly and competitive models, the firms’ profits from selling the primary good are independent of their reputation for quality. In an oligopoly, however, firms can tie the profits they earn from selling the primary product to the industry’s reputation for quality. When a firm loses its reputation for high quality, the ensuing price war erodes its profit from the primary product. Because of the risk of losing the profits from the primary good, firms are less tempted to shirk on quality, which makes a reputation for high quality easier to sustain.

5 Product Quality and Consumer Welfare

Our analysis so far has focused on identifying conditions under which firms are able to maintain a reputation of high quality. Although by assumption production of the high quality good is socially efficient, it is interesting to ask whether consumers are always better off in high quality equilibria than in low quality equilibria when both types of equilibria exist. In general it is difficult to unambiguously compare consumer welfare in these two types of equilibria, however, in the following proposition we identify conditions under which consumers are unambiguously worse off in high quality equilibria than in low quality equilibria. In other words, when these conditions are met, consumers are better off in the low quality equilibrium that they least prefer than in the high quality equilibrium that they most prefer.

Proposition 3 If

$$(\delta, n) \in \Phi \equiv \left\{ (\delta, n) : \delta \in \left[ \frac{c_h - c_l}{v_h - c_l}, \frac{c_h - c_l}{v_h - v_l} \right) \text{ and } n \in \left( \frac{1}{1 - \delta}, \frac{1}{1 - \delta \frac{v_h - v_l}{c_h - c_l}} \right) \right\},$$

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then high quality equilibria and low quality equilibria co-exist and consumers prefer any low quality equilibrium to every high quality equilibrium.

Proof. Recall from Proposition 1 that when a high quality equilibrium exists, which happens for all $\delta \geq \frac{c_h - c_l}{v_h - c_l}$ and $n \leq \frac{1}{1 - \delta \frac{v_h - v_l}{c_h - c_l}}$, the price range for the high quality good is

$$p \in \left[ c_h - \frac{(1 - \delta) c_l}{\delta}, \min \left\{ \frac{(1 - \delta) n((v_h - v_l) + c_l) - c_h}{(1 - \delta) n - 1}, v_h \right\} \right].$$

For $n > \frac{1}{1 - \delta}$, since tacit collusion among firms selling low quality products is impossible, in any low quality equilibrium, the low quality good will be sold at marginal cost $c_l$. Consumers prefer any low quality equilibrium to every high quality equilibrium if $v_l - c_l > v_h - \frac{c_h - (1 - \delta) c_l}{\delta}$. Note that

$$v_l - c_l = \left( v_h - \frac{c_h - (1 - \delta) c_l}{\delta} \right) = \frac{v_h - v_l}{\delta} \left( \frac{c_h - c_l}{v_h - v_l} - \delta \right) > 0 \text{ if and only if } \delta < \frac{c_h - c_l}{v_h - v_l}.$$

This completes the proof.

The area of the set $\Phi$ is shaded in Figure 1. Proposition 3 implies that enhancing efficiency needn’t increase consumer welfare and suggests that our finding that oligopoly interactions can increase quality need not be seen as an argument for relaxing anti-trust scrutiny.

6 Robustness: Consumer Heterogeneity and Product Differentiation

Proposition 2 shows that a duopoly market structure generates the widest range of discount factors that can support high quality and more generally, that the range of discount factors is always higher for oligopoly than monopoly or competition. That is, we find an inverted-U shaped relationship between market structure and the highest sustainable quality.

However we made several strong assumptions. First, we assumed consumers were homogeneous. In our simple model with unit demands this implied that the monopoly

Another strong assumption is perfect monitoring. It is more reasonable to assume that quality deviations are observed imperfectly. However, in general imperfect monitoring can dramatically
and competitive model generated the same quality. While this is a reasonable starting point, it is clearly not realistic in many environments. Swan (1970, 1972) established that the conditions on consumer demand under which product quality is the same under monopoly and competition are quite strong, even when quality is observable.

And second, we assumed that firms’ products were homogeneous. When firms’ products are differentiated, competition in the absence of tacit collusion is softened, and the incentives to tacitly collude and maintain product quality can be significantly altered. Below we briefly consider relaxing each of these assumptions.

**Heterogeneous Consumers**

Relaxing the assumption that consumers have homogeneous valuations for the low and high quality product (or equivalently the primary product and the upgrade) can be done in a number of different ways, however our comparison of the highest feasible product quality under the duopoly and monopoly market structures is likely to be quite robust. In general, this is because tacit collusion is always easiest to sustain with just two firms, so duopolists can most easily use the threat of a breakdown in tacit collusion to maintain a reputation for high quality production. Next we argue that as long as reputation for high quality production is easier to maintain under duopoly than monopoly, then the inverted-U shape relationship between quality and market structure is likely to be preserved.

First, note that the simplest way to introduce heterogeneity is to assume that consumers have heterogeneous valuations $v_h$ and $v_l$, but value the upgrade $(v_h - v_l)$ equally. That is, consumers valuations are $v_l$ and $v_h = v_l + \Delta$ where $v_l$ varies across consumers, but $\Delta$ does not. In an earlier version of our paper we showed that Lemmas 1 and 2, and Proposition 2, still hold when preferences are generalized in this way.

However, relaxing the assumption that consumers have homogeneous valuations over the upgrade is more interesting. Recall that in our discussion at the end of Section 3, we argued that when consumers are heterogeneous it may be either easier or harder for a monopolist to sustain high quality than competitive firms. If high quality is harder to sustain in competitive markets than under monopoly, the inverted-U relationship still exists. Duopolists can support high quality and the monopoly price change the incentives to shirk and might interact with market structure in subtle ways. In one simple extension in which firms imperfectly observe other firms’ deviations in quality that we considered, we found that the market structure that supported high quality most easily had a finite number of firms and could have strictly more than two firms if probability of detection by at least one rival was increasing in the numbers of firms.
for a wider range of discount factors than a monopolist (by using the threat of a price war), which is in turn a wider range than for competitive markets. And even if high quality is easier to sustain under competition than under monopoly, then since duopolists are likely to be able to support high quality at the competitive price whenever it is feasible to do so in more competitive markets (intuitively, holding price fixed, the incentive to deviate in quality is independent of the number of firms as long as there are two or more firms), so the range of discount factors that supports high quality is likely to be at least as wide as in competitive markets.

This suggests that a more general model with heterogeneous consumers (but homogeneous firms) might well find that intermediate market structures between duopoly and competition supported product quality most easily, however this remains to be shown.

**Product Differentiation**

Relaxing the assumption that firms’ products are undifferentiated (holding quality fixed) raises two questions:

First, and most obviously, we would like to know if the relationship we find between market structure and product quality is robust to the introduction of product differentiation. For example, for a given product space, as the numbers of firms (and equivalently the number of products they offer, each of which could be either high or low quality) varies, is high quality easiest to sustain in a duopoly market structure? Alternatively, given a large fixed number of products (each of which are either high or low quality), as the concentration of ownership of the products varies, is high quality easiest to sustain in a duopoly market structure?

Second, we would like to know if the relationship we find between market structure and product quality is robust to using product differentiation as a measure of market structure. The industrial organization literature has generally viewed both the number of firms and product differentiation as measures of product market competition. Recent work on the relationship between innovation and market structure has used product differentiation as the primary measure of market competitiveness (including Aghion, et al., 2005). More generally, both measures are frequently used. For example, in merger policy, product differentiation is used to define the market while the number and size of firms within that market is used to define market structure.

We consider each question below separately.
The impact of product differentiation on relationship between product quality and the number of firms

To answer the first question, we consider a simple spatial model product differentiation. Suppose that \( n \) firms are symmetrically located around a circle of unit circumference and that consumers are uniformly distributed with valuations \( v_h \) for high quality and \( v_l \) for low quality, and consumers have linear transportation costs \( t_d \), where \( d \) is the distance from the consumer to the firm.

Assume \( v_q >> c_q + t/2 \) for \( q \in \{l, h\} \) so the monopoly price when \( n = 1 \) is \( v_q - t/2 \) and the market is fully covered regardless of product quality. As above, we assume \( v_h - v_l > c_h - c_l \).

For \( n \geq 2 \), as long as high quality is sustainable, it follows that the industry profit-maximizing price is symmetric and equal to \( v_q - \frac{t}{2n} \) and again the market is fully covered for \( q \in \{l, h\} \).

For \( n \geq 2 \), it also follows that the static Nash price is symmetric and equal to \( c_q + \frac{t}{2n} \), and the static Nash profit is \( \frac{1}{n} \frac{L}{2m} = t/(2n^2) \).

For the monopolist, high quality is sustainable at price \( p = v_h - \frac{t}{2n} \) if

\[
\frac{v_h - \frac{t}{2n} - c_h}{1 - \delta} \geq (v_h - \frac{t}{2n} - c_l) + \delta \frac{v_l - \frac{t}{2n} - c_l}{1 - \delta},
\]

\[
\delta > \delta^Q \equiv \frac{c_h - c_l}{v_h - v_l} < 1,
\]

so the range of \( \delta \) that supports high quality is unchanged.

Now suppose firms tacitly collude. For \( n \geq 2 \), suppose a firm deviates in price as other firms produce high quality and charge a price \( p \). In general, the deviation profit can be complicated by the fact that the marginal customers may be choosing between the deviating firm and any of the other firms depending on the the deviating price. However, when \( t \) is small relative to \( v_l \) and \( v_h \), the optimal deviation is to steal the whole market. In this case, high quality and the collusive price are immune to price deviations (assuming consumers anticipate low quality from the deviator and that \( p \) is sufficiently high) if

\[
\frac{1}{n} \frac{(p - c_h)}{1 - \delta} \geq p - (v_h - v_l) - \frac{t}{2} - c_l + \delta \frac{1}{n} \frac{1}{2} \frac{t}{1 - \delta},
\]

that is, the present value of the equilibrium collusive profit forever weakly exceeds the short run gain from stealing the entire market (by cutting price by \( t/2 \)) and earning the static Nash profit thereafter. This implies that no firm will deviate in prices if
\[
\delta \geq \frac{(p - (v_h - v_l) + t/2 - c_l) - \frac{1}{n}(p - c_h)}{(p - (v_h - v_l) - c_l - t/2 - t/(2n^2))}
\]

or

\[
\delta \geq \delta^P(p, n, t) \equiv 1 - \frac{\frac{1}{n}(p - c_h) - \frac{t}{2n^2}}{(p - (v_h - v_l) - \frac{t}{2} - c_l - \frac{t}{2n^2})}
\]

which can be either increasing or decreasing in \(n\) (recall that it was strictly increasing when products were homogeneous).

For \(n \geq 2\), high quality and the price \(p\) are immune to quality deviations if

\[
\frac{\frac{1}{n}(p - c_h)}{1 - \delta} \geq \frac{1}{n}(p - c_l) + \delta \frac{\frac{1}{2} \frac{t}{2n}}{1 - \delta},
\]

or

\[
\delta \geq \delta^Q(p, n, t) \equiv \frac{c_h - c_l}{p - \frac{t}{2n} - c_l}.
\]

So \(d\delta^Q(p, n)/dn < 0\) and \(d\delta^Q(p, n)/dt > 0\), that is, greater competition (higher \(n\) and lower \(t\)) makes high quality easier to sustain. In contrast, the critical value of the discount factor was independent of \(n\) when products were homogeneous. Intuitively, competition reduces a firm’s static Nash profits even more than it reduces a firm’s equilibrium path profits, so the incentive to deviate in quality is reduced.

It is straightforward to show that \(d\delta^P(p, n)/dp > 0\), and it is even easier to see that \(d\delta^Q(p, n)/dp < 0\), so high quality and tacit collusion are sustainable for the widest range of discount factors when \(\delta^P(p, n, t) = \delta^Q(p, n, t)\), or

\[
p = \frac{2n(v_h - v_l) + 2(n - 1)c_l + nt}{2n - 2},
\]

which implies that high quality is sustainable if and only if

\[
\delta \geq \hat{\delta}(n, t) \equiv \frac{c_h - c_l}{\frac{2n(v_h - v_l) + 2(n - 1)c_l + nt}{2n - 2} - \frac{t}{2n} - c_l}.
\]

This implies that when \(t\) is small, \(\hat{\delta}(2, t) < \delta^Q_m\) and \(d\hat{\delta}(n, t)/dn > 0\) for \(n \geq 2\). In other words, the inverted-U shape we find in the undifferentiated product model is preserved.
The relationship between product quality and the extent of product differentiation

Understanding the relationship between product differentiation (holding the number of firms fixed) and firms’ ability to sustain high quality while tacitly colluding is more challenging. In many contexts, reductions in product differentiation and increases in number of firms have a similar impact, and the industrial organization literature often treats these two changes as interchangeable. But the natural similarity of these two measures of competitiveness follows from comparative statics on equilibria of static games and doesn’t easily carry over to the equilibria of repeated games. Some papers, like Wernerfelt (1988) and Ross (1992), are consistent with static games and find that tacit collusion is easier as products become more differentiated, but these papers nevertheless show that the joint profit-maximizing output can be supported for sufficiently high discount factors as differentiation decreases. Other papers, including Raith (1996), argue that tacit collusion is easier as products become less differentiated. The distinction is important. In the limit as \( n \to \infty \), the equilibrium price falls to the static Nash equilibrium price regardless of the discount factor. However, in the limit as products become perfectly homogeneous the equilibrium price need not fall to the static Nash equilibrium price as long as the number of firms is sufficiently small, or the discount rate is sufficiently large.

While there are many ways to model horizontal product differentiation, it is possible to say something about how changes in horizontal product differentiation would impact product quality.

From (22) it follows that

\[
\frac{d\hat{\delta}(n,t)}{dt} = \frac{-2n(c_h - c_l) (n - 1) ((n - 1)^2 + n)}{((n^2 + 1) t + 2n^2 (v_h - v_l) - nt)^2} < 0.
\]

That is, holding \( n \) fixed (and for sufficiently small \( t \)), product quality is easiest to sustain when products are more differentiated. However, since the expression of \( \hat{\delta}(n,t) \) is valid only for \( t \) sufficiently small, in general, the relationship between differentiation and quality need not be monotonic and might even have an inverted-U shape.

While the simple model analyzed above is very special, it is clear that in models of dynamic pricing and tacit collusion, the extent of product differentiation and the number of firms can have very different effects on product quality.
7 Conclusion

Using a repeated moral hazard model of experience goods, we show that firms in an oligopoly can more easily maintain a reputation for a high quality than a monopolist or firms in a competitive market. When firms in an oligopoly expect that shirking on quality will start a price war, the long-run cost of quality shirking is increased. Hence, it is easier to sustain a reputation for high quality in an oligopoly market. We also find that while producing high quality is socially efficient, consumers may prefer low quality, that is, consumers may capture more consumer surplus in any of the low quality equilibria then in all of the high quality equilibria.

Our results characterize the relationship between market structure and the highest sustainable product quality, but our model has multiple equilibria and low quality is always an equilibrium of the game. While adding a commitment type could eliminate the multiplicity, a commitment type in a game with both tacit price collusion and quality choice does not seem realistic.

Finally, an important way that our analysis differs from previous work on the impact of competition on reputations is that we relax the assumption that consumers’ expectations of a firm’s quality are invariant to the price that it charges (or the quantity it sells). Both Kranton (2003) and Bar-Isaac (2005) use this assumption to refine the set of equilibrium they consider. We show that relaxing this restriction dramatically increases the potential for oligopolists to sustain reputations for high quality products.

We think that Kranton’s and Bar Issac’s restriction may not be appropriate, particularly when consumers are sophisticated. Specifically, we question whether it is reasonable to rule out equilibria with high quality products by assuming that a off-the-equilibrium-path price cut leads to a subgame in which the firm’s equilibrium strategy is to continue to offer high quality. Nevertheless, the level of sophistication necessary for consumers to anticipate quality changes following a fall in prices is demanding, so we expect our model to be empirically relevant only when buyers are relatively sophisticated.
References


