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No Pain, No Gain: A Critical Review of the Literature on Signaling Unobservable Product Quality

Recent research in information economics has focused on signals as mechanisms to solve problems that arise under asymmetric information. A firm or individual credibly communicates the level of some unobservable element in a transaction by providing an observable signal. When applied to conveying product quality information, this issue is of particular interest to the discipline of marketing. In this article, the authors focus on the ways a firm may signal the unobservable quality of its products through several marketing-mix variables. The authors develop a typology that classifies signals and discuss the available empirical evidence on the signaling properties of several marketing variables. They consider managerial implications of signaling and outline an agenda for future empirical research.

A consumer is considering the purchase of a new computer that is being advertised a great deal by a relatively new firm. Should the consumer interpret the high volume of advertising as informative about the quality of the computer?

A new manufacturer of a consumer product is offering a low introductory price. Should this low price be interpreted as evidence of low quality?

Traditional perspectives on the effects of information such as advertising and price have emphasized information acquisition, integration, and retrieval in consumer judgment and choice (see Bettman 1979; Rao and Monroe 1988). We propose that this traditional approach should be supplemented with an emerging tradition in information economics (Bergen, Dutta, and Walker 1992; Mishra, Heide, and Cort 1998; Rao and Monroe 1996). The information economics approach is based on the premise that different parties to a transaction often have different amounts of information regarding the transaction, and this information asymmetry has implications for the terms of the transaction and the relationship between the parties. In particular, when one party lacks information that the other party has, the first party may make inferences from the information provided by the second party, and this inference formation should play a role in the information the second party chooses to provide. This problem of information asymmetry is now recognized as an important consideration in the study of marketplace exchanges in the disciplines of accounting, finance, labor economics, organizational behavior, and marketing.

Information asymmetry may exist between transacting parties in a variety of settings, including employers uncertain about the abilities of workers (Spence 1973), insurance providers uncertain about the health of insurance purchasers (Rothschild and Stiglitz 1976), and organizational buyers uncertain about the abilities of vendors (Stump and Heide 1996). Because of its central role in consumer decision making and marketing strategy, in this article, we focus on buyers' uncertainty about the quality of the product provided by sellers.

We examine solutions to one particular type of information asymmetry problem, *adverse selection*, which occurs when one party lacks the skills necessary to provide high quality yet claims to possess those skills (Eisenhardt 1989; Mishra, Heide, and Cort 1998). One possible solution to this problem is the use of *signals*, which are actions that parties take to reveal their true types (e.g., skill level). Quality signals can be transmitted in many forms, including brand name, price, warranty, and advertising expenditures. These variables represent fundamental choices that marketing managers make, including what to call a new product, how much to charge for it, whether to offer a warranty, and how much to spend on advertising. Although extensive behavioral research exists on how cues such as price, brand name, and store name affect consumer perceptions and choice (for an integrative review, see Rao and Monroe 1989), that approach views cues as shortcuts used by cognitively "lazy" consumers. Signaling posits a "rational" consumer who expects a firm to honor the implicit commitment conveyed through a signal because not honoring the commitment is economically unwise. Thus, unlike the behavioral perspective, the signaling approach considers the firm's incentives.

The signaling perspective has spawned several mathematical models that describe when and how a firm may suc-

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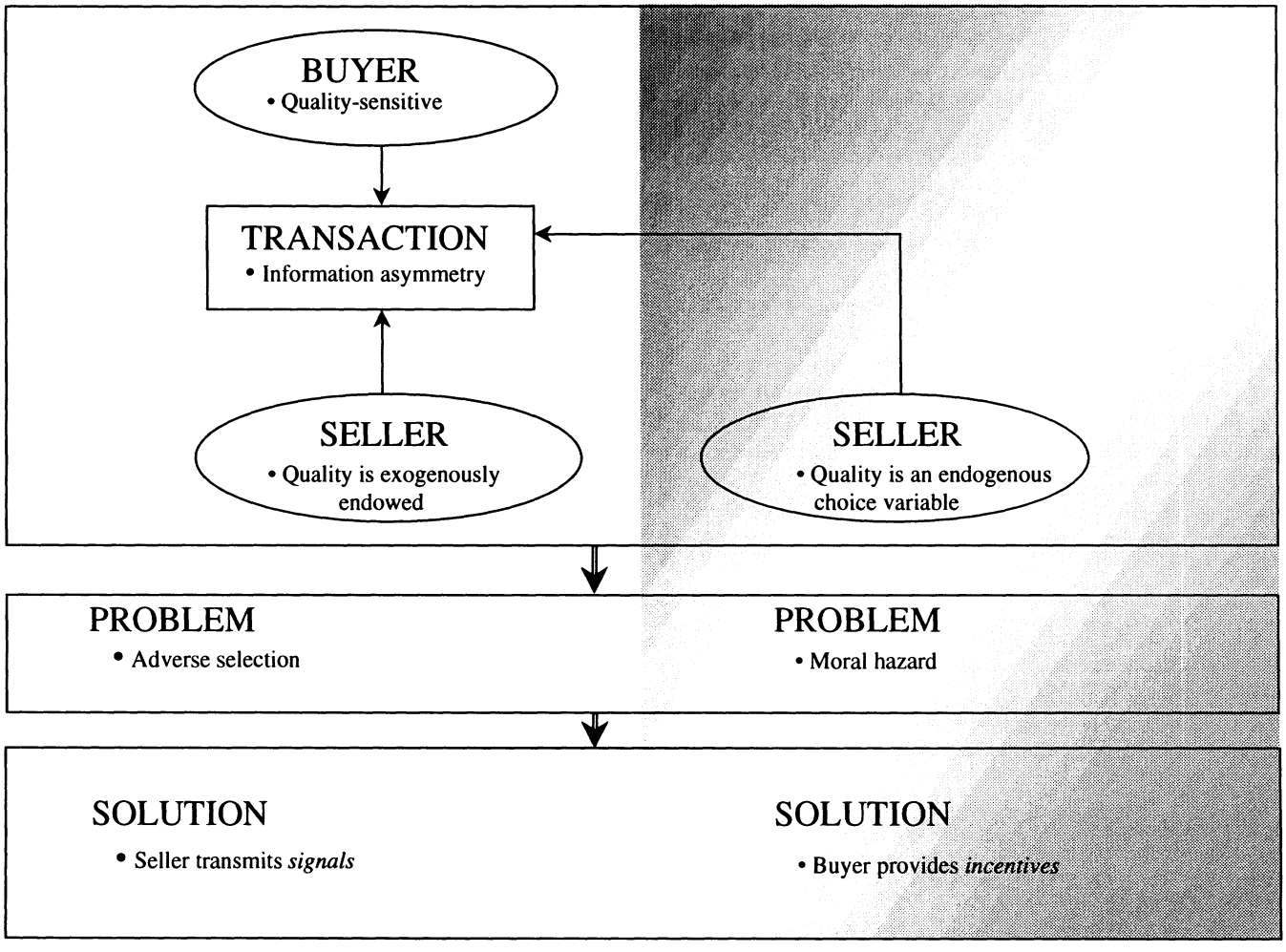
cessfully signal. Our basic purpose is to bring some coherence to these models and take stock of the current state of knowledge about quality signaling. Specifically, in this article, we (1) describe how marketing signals work, (2) develop a typology that sorts signals into theoretically justifiable and managerially useful categories, (3) highlight how signaling theory can help managers make marketing-mix decisions, and (4) outline an agenda for further research. In the process, we identify important assumptions of the approach, describe empirical evidence, and provide managerially pertinent prescriptions that speak to issues such as those raised in the opening vignettes.

The focus of the article is different from other recent reviews in marketing. Bergen, Dutta, and Walker (1992) provide an overview of information asymmetry in the broader context of agency theory, but their discussion of signaling is limited; as they note, they "only scratched the surface of the wide range of ... [signals] available to marketers" (p. 16). Similarly, Rindfleisch and Heide (1997) critically evaluate the contributions to marketing of transaction cost analysis, a close cousin to signaling theory. Like signaling, transaction cost analysis speaks to appropriate governance structures that mitigate information problems, but unlike signaling, its primary focus is postcontractual relationship management rather than precontractual information asymmetry. Finally, our context of firm-to-consumer signals is different from research on how firms signal to competitors (Heil and Langvardt 1994).

Asymmetric Information

Figure 1 summarizes the key issues in addressing information asymmetry about product quality, which occurs for "experience products" (Nelson 1974), that is, products whose quality can be evaluated only after purchase. Quality-sensitive buyers are unsure about the true quality of the seller's product. Information asymmetry can occur in two settings: *adverse selection*, in which the seller's unobservable quality is fixed and does not change from one transaction to the next (the unshaded area in the figure), and *moral hazard*, in which the seller can change quality from one transaction to the next (the shaded area). Although both situations involve buyers who are suspicious of sellers' quality claims, the mechanisms to resolve the information asymmetry differ. Adverse selection situations may be resolved by signals, whereas moral hazard problems may be resolved by incentives. Because the

Figure 1
Key Issues in Addressing Information Asymmetry



incentive-based mechanism to resolve moral hazard problems has been addressed in detail elsewhere (Rao and Monroe 1996), we focus on adverse selection here.

Adverse Selection

Because the seller cannot change quality from one transaction to the next in adverse-selection situations, the information problem disappears when the buyer learns about quality. Therefore, the key problem for the high-quality seller[1] is to induce trial and reveal quality. However, sellers' attempts to induce trial may not be successful, because quality-sensitive buyers may not want to suffer the negative consequences of poor quality.

The solution to the adverse-selection problem is the provision of a signal, which yields outcomes that are economically the best for high-quality firms, but low-quality firms can do better by not signaling (for a seminal article on signaling in job markets, see Spence 1973). To illustrate, consider the signaling and nonsignaling payoffs for high- and low-quality firms:

	Signal	Do Not Signal
High-quality firms	A	B
Low-quality firms	C	D

Signaling is a viable strategy when two conditions hold: (1) For the high-quality firm, the gains from signaling outweigh the gains from any other strategy; that is, A > B; and (2) for the low-quality firm, a nonsignaling strategy provides a bigger payoff than does signaling; that is, D > C. Under these conditions, a "separating equilibrium" occurs, in which firms self-select into the more profitable strategy, making it rational for consumers to infer that the firm that transmits a signal is the high-quality provider. If the low-quality firm were to mimic the high-quality firm's signal, it would lose money either directly (because signaling results in higher costs that will be forfeit when the low-quality seller's true quality is discovered) or indirectly (because of the opportunity costs of forgone strategy choices).[2]

If the payoff values in the previous schematic were such that A > B and C > D, both firms would be better off signaling. In such circumstances, consumers cannot distinguish between low- and high-quality sellers, which results in a "pooling equilibrium." A pooling equilibrium may occur when the gains from falsely claiming high quality outweigh the losses from being discovered.

As described in the Appendix, the costs associated with signaling are, in part, determined by the high-quality firm, which seeks to separate itself from the low-quality firm. The magnitude of such costs or potential costs serves as the high-quality firm's "bond" (Ippolito 1990), because the expenditure associated with the signal will be forfeit if false. Consequently, when signaling costs reach a particular level, low-quality firms will not signal. As long as this cost is low enough to make signaling attractive for the high-quality firm, it is the optimal signaling cost or bond. To understand better the properties of various signals and identify marketing implications, we next develop a typology that classifies signals on the basis of the bond at stake.

A Typology of Marketing Signals

In Table 1, we describe the typology. The primary classification is based on the monetary consequence incurred by the firm. We distinguish between *default-independent signals*, which are signals in which the monetary loss occurs independently of whether the firm defaults on its claim, and *default-contingent signals*, which are signals in which the monetary loss occurs only when the firm defaults on its claim. For example, signals such as investments in advertising and reputation involve up-front expenditures by the firm and are therefore incurred regardless of whether the firm's claim is true or false (i.e., in-equilibrium and out-of-equilibrium situations). Conversely, signals such as a high price or a manufacturer's warranty do not involve up-front expenditures and will prove to be monetarily detrimental only to firms that default on their claims (i.e., for out-of-equilibrium situations). Besides being theoretically grounded, this distinction is also managerially relevant, because signals that involve up-front expenditures are cash intensive, whereas signals that do not involve up-front expenditures may be funded by profits from sales to quality-sensitive buyers.[3]

Each of these broad categories can be further subdivided on the basis of the nature of the bond at stake. The up-front costs of default-independent signals differ as to whether the expenditure depends on an actual sale. *Sale-independent* default-independent signals, such as investments in advertising and brand equity, involve expenditures that occur whether or not a sale occurs. Conversely, *sale-contingent* signals, such as a low introductory price and slotting allowances, involve expenditures only in the presence of a sales transaction. As we discuss subsequently, this distinction leads to different conditions in which managers may use sale-independent and sale-contingent signals.

Finally, the bond underlying default-contingent signals is based on the potential of future consequences (i.e., future profits at risk) should the firm's quality claim turn out to be false. Therefore, the nature of the potential monetary loss forms the basis for classifying default-contingent signals. Under default-contingent signals, we define *revenue-risking* signals, such as high price, as signals that offer the firm's future revenues as a hostage and *cost-risking* signals, such as

[1]For presentational convenience, we refer to sellers of high-quality products as high-quality firms and to sellers of low-quality products as low-quality firms.

[2]An important, technical issue in the construction of signaling models is the need to restrict out-of-equilibrium beliefs. For example, the signal recipient may hold beliefs that result in an interpretation other than that intended by the signal transmitter, as a consequence of which several other equilibria may be possible. Given the general, nontechnical purpose of our article, we do not discuss this issue here but refer the interested reader to Kreps (1990, particularly Chapter 12) and Cho and Kreps (1987) for a more technical discussion.

[3]Other classification schemes exist. For example, dissipative signals refer to inefficiencies relative to first best (i.e., they involve wasteful expenditures such as "burning money" through Super Bowl advertising), whereas nondissipative signals have no "deadweight loss" associated with them (Bhattacharya 1980). Rao, Qu, and Ruekert (1999) recently used the dissipative/nondissipative terminology in a manner that roughly corresponds with our terminology.

TABLE 1
Characteristics of Signals

	Default-Independent Signals		Default-Contingent Signals	
	Sale-Independent	Sale-Contingent	Revenue-Risking	Cost-Risking
Examples	Advertising Brand name Retailer investment in reputation	Low introductory price Coupons Slotting allowances	High price Brand vulnerability	Warranties Money-back guarantees
Characteristic	Publicly visible expenditures before sale	Private expenditures during sales transaction	Future revenues at risk	Future costs at risk
Repeat purchase	Is important	Is important	Is important	Irrelevant
Monetary loss	Fixed	Variable or semi-variable	In the future	In the future
Secondary benefits	Buyer does not receive direct utility	Buyer receives direct utility	Buyer does not receive direct utility	Buyer receives direct utility
Appropriate when	Buyer cannot be identified easily	Buyer can be identified easily	Frequently purchased nondurables	Durables
Potential for abuse by consumer	None	High	None	High

warranties, as signals that offer the firm's costs as a hostage. Next, we describe each of these categories and compare their characteristics.

Default-Independent Signals of Unobservable Quality

Signals that involve the up-front expenditure of money fall into this category. The fundamental rationale behind default-independent signals is that the firm spends money now, expecting to recover it in the future, and such an expenditure would not have occurred had there been no information asymmetry. Rational consumers should realize that firms engaging in current expenditures that yield suboptimal profits will attempt to recoup these expenditures through future sales. These future sales would not occur if quality-related claims turned out to be false; therefore, quality-related claims made by firms that incur such costs must be true.

Sale-Independent Default-Independent Signals

Sale-independent default-independent signals are actions that occur regardless of whether anyone buys the product. Two marketing expenditures that fall into this category are advertising expenditures and investments in brand names.

Advertising expenditures. According to the information economics perspective, advertising content is informative about the quality of search attributes, and advertising execution (the quantity of advertising, its memorability, and the like) is informative about the quality of experience attributes (Nelson 1974). Advertising content is informative for search attributes, because the consumer can verify ad copy claims before purchasing. For experience attributes, firms could make a false claim, and the consumer would not be able to assess its veracity before purchasing. However, if a firm spends large sums of money on advertising, claims about unobservable quality must be true or the firm would not recoup this expenditure. If a low-quality firm advertised heavily, it would induce trial, and its true (low) quality would be revealed; because no future purchases would occur, it would not recover the costs of advertising (Bagwell and Ramey 1988; Kihlstrom and Riordan 1984; Milgrom and Roberts 1986; Nelson 1974).

Brand name. Brand names can communicate unobservable quality (Erdem and Swait 1998), because branded sellers make several types of investments to build brand equity, including advertising, product design, and packaging modifications. These investments represent current expenditures that must be recouped from future sales. To the extent that a low-quality seller will lose this investment because future sales will not accrue after low quality is revealed, the low-quality seller has an incentive not to make investments in brand name. Conversely, sellers' investments in brand equity should raise the credibility of claims about unobservable quality.

Evidence. Several correlational studies have examined whether product quality is affected by advertising (Archibald, Haulman, and Moody 1983; Caves and Greene 1996; Mizuno and Odagiri 1989; Rotfeld and Rotzoll 1976) and brand name (Erdem 1998; Erdem and Swait 1998). These studies find general support for signaling predictions for both low-priced consumer goods (Rotfeld and Rotzoll 1976) and consumer durables (Phillips, Chang, and Buzzell 1983). Experimental work in advertising and brand equity is also consistent with signaling theory, though it appears that consumers do not spontaneously evoke the sophisticated rationale of signaling theory when making quality judgments (Rao, Qu, and Ruekert 1999) and may infer desperation on the part of the firm from high levels of prelaunch

advertising expenditures (Kirmani 1990, 1997; Kirmani and Wright 1989).

Sale-Contingent Default-Independent Signals

In the case of sale-contingent signals, the expenditure associated with the signal occurs at the time of the sale and provides essentially the same information as a sale-independent signal, that is, telling the buyer that the seller plans to recover signal costs through future profits. Two examples of sale-contingent signals are a low introductory price and slotting allowances.

Low introductory price. The possibility that low introductory prices (i.e., a price that is below the "full-information price") may sometimes communicate high unobservable quality has received little attention in the marketing literature. A low introductory price can serve as a signal of quality in the same way as advertising: The seller is communicating to the buyer a short-term loss to induce trial (Schmalensee 1978). This loss occurs in the form of revenues forgone from charging a price commensurate with the quality of the product. In general, the selling price is visibly below the marginal cost of production, thus alerting the buyer to the following implicit reasoning: "I am spending money wastefully now, but because my quality is good, I will recoup this money in the future from repeat purchases." The seller's plan is to raise product prices to a level commensurate with the product's true quality after this quality is established (Tirole 1988). If it turns out that the seller has sold a low-quality product, customers will not repeat purchase at the postintroductory high price, and the losses from the low introductory price are irrevocable.

There are some important technical requirements for a low introductory price strategy to work. First, it should be clear to the consumer that the seller's price is below the full-information price, that is, that the selling price is below the seller's marginal cost of production. Offers of compact discs for a penny and "five books for five bucks" may suggest a submarginal cost price. Second, the low price must be lower than any price that can be offered by a low-price/low-quality competitor (i.e., the competitor's marginal cost). Otherwise, a competitor will simply mimic the low price, and a pooling equilibrium will occur. Third, there must be a sufficiently large segment of quality-sensitive buyers who will repurchase at the postintroduction high price because they value the high-quality product sufficiently. If the firm is unable to attract a large number of customers at the higher price, the cost of the signal will not be recovered. Fourth, the high-quality segment's reservation price should be higher than the postintroduction high price; otherwise, the high-quality firm will not be able to support its future price.

Slotting allowances. A slotting allowance represents a signal in a manufacturer-to-retailer context (Chu 1992; Lariviere and Padmanabhan 1997; Shaffer 1991; Sullivan 1997). Slotting allowances are up-front fees (as either lump sums or functions of the number of cases purchased by stores in the chain) paid by the manufacturer to the grocery store retailer for access to shelf space for new products. The argument has been made that such slotting allowances are willingly paid by manufacturers that are confident about the success of their new product introduction (i.e., the quality of the product from the standpoint of the retailer) (Chu 1992). A manufacturer that is not confident about the future success of a new product will likely balk at paying a slotting fee for fear of losing that investment. Thus, a slotting allowance functions as a default-independent signal that involves current expenditures (i.e., an up-front fee) that will be compensated for by future revenues (i.e., sales to grocery stores that profit from the successful new product and therefore repurchase).

Evidence. Little empirical evidence exists on the ability of sale-contingent default-independent signals to communicate unobservable quality. Dawar and Sarvary (1997) find no support for the argument that low introductory prices convey quality information. Sullivan (1997) examines secondary data about slotting allowances, and though she does not focus on the signaling issue, she is unable to dismiss the claim that slotting allowances signal new product demand. More recently, Rao and Mahi (2000) find no support for the signaling role of slotting allowances.

Commentary on Default-Independent Signals

As we noted previously, default-independent signals involve up-front costs that are rational if future sales generate sufficient margins to compensate for the costs of signaling. Repeat purchase is likely to occur only if the claims about unobservable quality are true. Thus, default-independent signals are an appropriate signaling device for products when repeat purchase is likely to occur. More generally, current buyers should have an impact on the probability of future sales because they are likely either to engage in repeat purchase or to influence others' purchase probabilities (e.g., they may be opinion leaders). Conversely, default-independent signals are inappropriate when current buyers do not influence future sales.

Sale-independent versus sale-contingent default-independent signals. Sale-independent and sale-contingent default-independent signals differ on several important dimensions (Table 1). A key distinction is that sale-independent signals result in a monetary loss regardless of whether the product is sold, whereas sale-contingent signals involve a monetary loss only when a transaction occurs. This property makes sale-independent signals a fixed cost and sale-contingent signals a variable cost, which has implications for a firm's ability to engage in a price war (Rao, Bergen, and Davis 2000).

Another key distinction is that sale-independent signals tend to address a broad audience that may include a substantial number of nonbuyers, as is the case for advertisements for luxury automobiles during the Super Bowl. Sale-contingent signals, in contrast, are generally targeted toward buyers; for example, only someone who buys the product truly knows that the seller has incurred a loss on the unit sold at a low introductory price.

Finally, sale-independent signals provide less of a direct benefit to the buyer than do sale-contingent signals. For example, both low introductory prices and slotting allowances help reduce the buyer's costs. Money changes hands in the form of consumers' surplus (the difference between the full-information price and the actual low introductory price) in

the case of a low introductory price, and in the form of a transfer payment in the case of slotting allowances. Notice that this money would not have changed hands under full information. In contrast, advertising and brand names typically do not provide direct utility, as no money is transferred from seller to buyer.

Default-Contingent Signals of Unobservable Quality

Whereas default-independent signals involve up-front expenditures, default-contingent signals are costless at the time the signal is transmitted, because the firm does not incur up-front expenditures relative to the expenditures that would be incurred in the absence of information asymmetry. These signals involve credible commitments to suffer future negative consequences if the product turns out to be of poor quality. Because such a consequence would only be visited on a firm that claimed to be of high quality when it actually was of low quality, a low-quality firm will be better off not making such a false claim; a low-quality firm will not offer commitments that will place it at future risk.

The credible commitment (or bond) that a firm offers can be of two types: loss of potential revenue (revenues at risk) or increases in costs (costs at risk). We first discuss revenue-risking default-contingent signals, followed by cost-risking default-contingent signals.

Revenue-Risking Default-Contingent Signals

The underlying rationale for revenue-risking default-contingent signals is that enhanced future revenues are available only to high-quality firms that employ the signal; thus, low-quality firms will be better off not employing the signal. An example of a revenue-risking signal is the charging of a high price.[4]

Although the notion that high prices may convey quality is well established in the behavioral marketing literature (see Rao and Monroe 1989), the signaling underpinnings of a high price may be less clear. A high price will be more profitable for the high- than the low-quality firm when there exists a small group of quality-sensitive buyers who are willing to pay a high price for high quality but will not repurchase if the product turns out to be of low quality. In addition, there needs to be a large group of quality-insensitive buyers who are price sensitive and will not buy at the high price. In such a setting, if the low-quality firm chooses a high price, it will reap profits from quality-sensitive buyers once but will lose profits from price-sensitive buyers who will not buy at the high price. Although the firm may reduce the price after quality is revealed, the single-period gains from high prices will be more than negated by the single-period losses from not having sold to the price-sensitive segment in the first period. In contrast, if the high-quality firm charges a high price, the quality-sensitive customers will purchase from it and, upon discovering its true quality, will repurchase. For the high-quality firm, this series of purchases is more profitable in the long run than is charging a low price and catering to the quality-insensitive segment (Tirole 1989).

The reader may be puzzled by the observation that both high and low (introductory) prices can serve as signals. The key condition that drives the choice of a high or low introductory price is the relative profitability of the quality- and price-sensitive consumer segments. For a high-price strategy to work, low-quality firms must find it profitable to charge low prices, whereas high-quality firms must find it profitable to charge high prices. One circumstance that will result in this separation is based on the quality-sensitive segment's willingness to pay for superior quality. That willingness to pay must be sufficiently high to sustain long-term high prices but not so high that the first-period (uninformed) purchase from a low-quality firm at the high price will be more profitable for the low-quality firm than profits that accrue from low-priced sales to the price-sensitive segment.

From a managerial standpoint, the firm incurs no cash outlay when signaling with a high price, whereas it incurs a cost (direct or opportunity) when signaling with a low introductory price (because this low price is below the full-information price). In addition, whereas charging a high price is a long-term strategy, a low introductory price is temporary, because sales at a current low price will need to be offset by future high-priced sales. In contrast, no forgone current profits need to be recouped in the case of a high price.

Evidence. Although the behavioral literature on price–perceived quality relationships is substantial (see Rao and Monroe 1988, 1989), the empirical literature on price as a signal is sparse. Gerstner (1985) finds some equivocal evidence on the signaling ability of price; Tellis and Wernerfelt (1987) observe that price–quality correlations tend to be stronger when quality is important (for durables, when quality is expected to provide returns over a longer period of time) and unobservable (for packaged goods, the quality of which is not directly observable by inspection).

Cost-Risking Default-Contingent Signals

Cost-risking default-contingent signals do not involve monetary expenditures up front yet credibly convey information that false claims would involve a direct cost to the firm. The principal examples of this type of signal are performance warranties and money-back guarantees. Whereas manufacturers' performance warranties generally cover product breakdown and replacement of parts, money-back guarantees are typically of shorter duration but allow consumers to return the product without explanation.

The premise underlying the warranty signal is that firms selling low-quality products will face higher repair costs for the same level of warranty than will high-quality firms, because low-quality firms' products are likely to require more frequent repair. Consequently, a low-quality firm will self-select a strategy that offers relatively poor warranties, and

[4]Other examples of default-contingent signals that risk future revenues include umbrella branding (Wernerfelt 1988), which posts the future sales of existing brands as a bond when a new product is launched under the umbrella brand name. Similarly, a new brand without a reputation may be able to claim successfully that it is vulnerable to consumer sanction and thus signal high quality (Rao, Qu, and Ruekert 1999). Note, however, to the extent that a brand name uses a sunk investment in reputation as a bond, the signal is a default-independent one (Erdem 1998).

rational consumers can infer unobservable quality from the level of warranty coverage.

Like other default-contingent signals, the warranty signal is costless at the time it is offered. Its bonding ability accrues from the future costs a firm will incur if the product does not live up to its warranted quality claim. Note that this signal will work only if the provision of a good warranty by a low-quality seller raises the seller's costs (and price) to a level higher than that of the high-quality seller. If the low-quality seller can offer a good warranty and successfully absorb the higher costs of warranty fulfillment through charging a higher price (which is still lower than that of the high quality-seller), a pooling equilibrium will occur, and warranties will not be a successful signal of quality (Grossman 1981; Lutz 1989; Spence 1977).

Evidence. Correlational studies (Kelley 1988; Wiener 1985) suggest that warranties signal reliability of durable goods, whereas one experimental study (Boulding and Kirmani 1993) suggests that warranties successfully signal only for reputable firms.

Commentary on Default-Contingent Signals

Default-contingent signals involve no expenditure of money; rather, future earnings are staked to credibly claim unobservable quality. Although there are cash-flow advantages to using default-independent versus default-contingent signals, that no direct costs are incurred in the current period makes default-contingent signals potentially less credible. In other words, because the reasoning regarding future profits at stake is relatively subtle, consumers will need to be alerted to this reasoning (e.g., Rao, Qu, and Ruekert 1999).

In addition, consumers sometimes may not believe that default-contingent signals place the firm at risk. For example, consumers may be suspicious of warranty claims, because warranties offered by fly-by-night firms may not be easy to enforce. The presence of a legal regime that ensures that a low-quality seller cannot renege on its warranty commitments without suffering huge costs is one way to make the warranty claim credible.

Similarly, for revenue-risking signals, the high-quality firm's claim that its future profits are at risk whereas those of a low-quality firm are not is a sophisticated argument. Such an argument may be made in business-to-business markets, perhaps during a sales presentation in which the high-quality seller demonstrates the long-term profitability of a particular customer or account (Rao 1993). It is likely to be more difficult to make in mass markets.

Revenue-risking versus cost-risking default-contingent signals. As is summarized in Table 1, there are several points of distinction between default-contingent signals that risk revenues and those that risk costs. Chief among these is the requirement for repeat purchase for revenue-risking but not for cost-risking signals. One important implication of this distinction is that revenue-risking signals are self-enforcing; it is in the economic self-interest of the firm to honor its claims about unobservable quality. In contrast, cost-risking signals require an additional mechanism, such as a legal regime or the brand's reputation, to ensure that the signal works. For example, a warranty offered by a fly-by-night firm without a reputation in a country with no legal recourse for consumers in the case of product failure is not enforceable and thus cannot serve as a signal. Moreover, because repeat purchase is unnecessary for cost-risking signals, these signals are particularly appropriate for durables, which are typified by long interpurchase intervals.

In addition, cost-risking default-contingent signals may represent a liability for the firm. Because warranties provide insurance against product failure, they may attract buyers who are careless in using the product or abuse the terms of the warranty (Cooper and Ross 1985; Lutz 1989). For example, Peterson and Hoffer (1994) report that insurance claims have increased for cars equipped with airbags, perhaps because drivers of such cars drive less carefully. Similarly, consumers can order and copy a piece of software or a compact disc and then return it claiming performance failure (Padmanabhan and Png 1995). The presence of a sufficient number of consumers who misuse a product when assured of inexpensive repair or replacements or return products that perform satisfactorily raises the cost of warranty fulfillment even for high-quality firms to a prohibitive level, which leads to a pooling equilibrium. In contrast, for revenue-risking default-contingent signals, the presence of undesirable buyers is not a problem; all that is necessary is a sufficiently large number of quality-sensitive buyers who will repurchase.

Having discussed the basic aspects of signaling theory, we now turn to a critical evaluation of the theory. In the next section, we reiterate the general and specific assumptions of signaling theory, discussing their applicability to real-world settings. We then consider managerial implications, presenting guidelines on which signals to employ in different circumstances. Finally, we outline directions for future marketing research on signaling.

A Critical Evaluation of Signaling Theory

Conditions for Successful Signal Transmission

Here we examine in detail four assumptions of signaling theory that relate to the issue of information asymmetry: prepurchase information scarcity, postpurchase information clarity, payoff transparency, and bond vulnerability.

Prepurchase information scarcity. Signaling is most useful for products whose quality is unknown before purchase, such as experience goods. If product quality is readily discernible or consumers are completely informed, the information problem is attenuated. Thus, signaling may not be appropriate for search products, well-known or mature products, or consumer markets with highly familiar buyers. Signaling may be particularly effective in markets for relatively new products or products about which consumers are relatively uninformed but are quality sensitive. For example, the market for baby food is populated by buyers who enter and exit fairly quickly and may not have the opportunity to develop expertise in the product category. This segment's lack of information and its risk aversion make it an appropriate target for a signal.

Postpurchase information clarity. If postpurchase inspection does not unambiguously reveal quality, consumers are unlikely to be able to exact retribution on the

offending seller, and signaling will likely not work. Therefore, signals are unlikely to convey quality for credence products, whose quality is not discernible even after purchase and use (Darby and Karni 1973). Similarly, signals are less useful for situations in which violations of quality claims cannot be unambiguously established after purchase. For example, a 1000-hour warranty on a light bulb is likely not a useful signal, because most consumers know they will not track the number of hours a light bulb has been left on and thus will not enforce the warranty.

Payoff transparency. Perhaps the greatest criticism against signaling models is that it assumes consumers and firms have knowledge of costs and other payoffs. On the one hand, consumers are supposed to be unable to evaluate quality before purchase. On the other hand, they are deemed to know vendors' margin and market share data, as well as the size of quality-sensitive segments in the market. Furthermore, it is assumed that firms are rational and aware of their own cost structures, an assumption that can be called into question. Perhaps only in business-to-business markets (e.g., in government contracts) will buyers be able to extract such cost information from vendors.

Bond vulnerability. Signaling is likely to fail when consumers do not believe that the bond posted by the firm is truly at risk. For example, for default-independent signals and in revenue-risking default-contingent signals, the principal mechanism to ensure the economic self-interest of the firm is profits from repeat purchase. However, consumers may not be aware of the manner in which this mechanism is supposed to operate. Specifically, consumers may be unaware of their own role in enforcing quality through the express or implied threat of boycott. Consequently, they may not correctly interpret the signaling rationale behind signals that rely on repeat purchase, which suggests that firms may be well advised to communicate this rationale.

Another reason consumers may suspect that the bond is not truly at risk is if the firm can find uninformed quality-sensitive consumers. For example, roadside restaurants may charge a high price while offering low quality, because they serve one-time customers who are separated from one another, which limits both repeat purchase and word of mouth. In such situations, signals that rely on repeat purchase will not be credible (Wolinsky 1983).

For signals that are not self-enforcing (such as warranties), the firm needs to operate in an environment in which the legal system makes the claim credible. Warranties are likely to be valueless at an airport duty-free shop for a domestic brand name unless the traveler plans to return to that country and use the product there. Furthermore, to the extent that consumer moral hazard is an issue, warranties are less likely to be credible, which renders them inappropriate for products for which the consumer's effort in caretaking is critical to product performance (Lutz and Padmanabhan 1995).

Finally, signals may not be credible when the signaling channel is so noisy that consumers fail to realize that the firm has used a costly signal (Hertzendorf 1993). In such situations, firms need to remind (or inform) consumers that costly expenditures have been incurred. For example, at the point of purchase, consumers may forget that a firm engaged in Super Bowl advertising. Point-of-purchase reminders of the advertising may encourage recall of its expense (and signaling value). Similarly, consumers may recognize that warranty cards for durable gifts (e.g., video cameras, videocassette recorders) that are given during special occasions (e.g., seasonal holidays, birthdays, anniversaries, graduations) are often misplaced because of the number of gifts being opened and the attendant amounts of wrapping paper. Consequently, consumers may perceive the warranty as unenforceable. To guard against this, firms may benefit by ensuring that warranty information is retained by the retailer or mailed to the user separately.

In summary, signaling is most effective under conditions in which prepurchase information about quality is scarce, postpurchase information about quality is unambiguous, players are informed about the payoffs for both types of firms, and the bond is vulnerable to consumer sanction. Although the circumstances under which signaling may be an appropriate strategy are well described in the literature, managers have little guidance on which signals are best deployed in a particular situation. We turn to that issue next.

Managerial Implications

If signals are an appropriate mechanism to convey unobservable quality, firms will likely prefer to use the least expensive signal. However, the amount to be spent (or pledged) is the same for all signals. This amount should be just high enough to dissuade the low-quality firm from signaling, yet low enough to make signaling attractive for the high-quality firm.

To determine which type of signal is preferred in a given situation, we recommend that managers consider the factors that drive the behavior of three sets of players: consumers, competitors, and the company.

Consumers. If the necessary conditions for signaling are in place, issues of importance are as follows:

(1) Is the target audience readily identifiable? Because sale-contingent signals tend to involve costs only when a sale occurs and provide a direct benefit to buyers, firms should generally prefer to use sale-contingent signals over sale-independent signals. Sale-contingent signals may be an attractive way to signal unobservable quality for new products for which buyers are relatively easy to identify, such as a new medical device that will be useful to pediatric cardiologists. When a target segment cannot be easily defined, however, a sale-independent signal is more appropriate.

(2) Is there a fear of attracting the wrong type of buyer? The firm may be concerned that the wrong type of buyer may be attracted to the offer. For example, the offer of a sale-contingent signal such as a low introductory price may attract price-sensitive buyers who are not quality conscious. These buyers may take advantage of the low price and then not repeat purchase at the postintroductory high price. This behavior raises the costs of signaling and may make signaling prohibitively expensive.

(3) Is there significant opportunity for initial buyers to influence future sales directly or indirectly? If current buyers can affect the probability of future sales, because they are likely either to repeat purchase or to influence others' future purchase probabilities, signals that emphasize

repeat purchase should be considered. These include default-independent signals as well as revenue-risking default-contingent signals. If current buyers cannot influence future sales, cost-risking default-contingent signals enter the set of feasible options. Indeed, consumer information transfer may also obviate the need to use signals. For example, after a small group of informed quality-sensitive consumers starts to use the product, others may follow suit because they can rely on informed consumers' willingness to buy as evidence of high quality (Bagwell and Riordan 1991). Therefore, sellers may choose to inform a small fraction of quality-sensitive buyers and gain sales from all quality-sensitive buyers without having to invest in signals that communicate to all of them (Davis and Rao 1997). Expense-paid trips for opinion leaders (e.g., leading medical practitioners) to observe the operation of new technologies is a form of such information provision.

(4) How profitable is the quality-sensitive segment? Quality-sensitive buyers may vary in their willingness to pay for high quality. When buyers' willingness to pay is high, the high-quality firm will profit from sales to this segment, as will low-quality firms until their true (low) quality is discovered. Because the willingness to pay makes this segment attractive, high-quality sellers should use signals that provide gains from future rather than current sales (i.e., default-independent signals). Conversely, if quality-sensitive buyers' willingness to pay is relatively low, they are less attractive to low-quality sellers, and high-quality firms may choose signals that yield profitable sales in the current period (i.e., default-contingent signals). By the same logic, the size of the quality-sensitive segment should influence the choice of signal. If the quality-sensitive segment is relatively small, it is less attractive to the low-quality firm, and therefore the high-quality firm can signal using devices that emphasize current profits (i.e., default-contingent signals). Conversely, if the quality-sensitive segment is large, the benefits from falsely claiming high quality increase, which suggests that high-quality firms will need to employ signals that yield profits only after the first period (i.e., default-independent signals) to limit the low-quality firm's tendency to make a killing in the first period.

Competitors. High-quality firms may face a competitive environment in which other high-quality firms exist. The presence of these firms, all of whom are attempting to signal high quality, may have implications for the choice of signal.

(1) Is there a cash flow–related constraint for the firm? Cost-free signals (i.e., default-contingent signals) that rely solely on the pledge of future profits are attractive to cash-poor firms. For example, Chrysler offered a high (seven-year/70,000-mile) warranty to attract customers in the early 1990s, when it was in financial trouble. Using the warranty helped both increase sales (i.e., generate short-term revenue) and postpone long-term expenditures for warranty redemption. Conversely, a cash-rich, high-quality firm may choose to use a default-independent signal, such as advertising, relative to a competitor's default-contingent signal.

(2) Are there collaborators in association with whom a signal may be transmitted? Alternative means of signaling, such as using a brand ally (Rao, Qu, and Ruekert 1999) or a well-reputed retailer (Chu and Chu 1994), are options that exist for certain high-quality firms, based on their current relationships with vendors or channel members. For example, perhaps because of incumbency-based advantages, one high-quality firm may be able to use its association with another reputable firm (i.e., use the second firm's brand equity) as a signal, an option that may not exist for a competitor.

Company. Factors internal to the company and its technology may also have an impact on the type of signal used.

(1) What is the time lag between purchase and quality revelation? As has been noted in other commentaries (e.g., Rao and Monroe 1996), the speed with which an unobservable attribute's true level is revealed varies. Whether a sugar substitute has the disadvantage of an aftertaste is revealed immediately upon consumption, whereas the durability of an automobile tire is not revealed for several years. To the extent that quality is revealed immediately after purchase and use, the high-quality firm can anticipate profits in the second period. However, if quality revelation takes a long time, profits are deferred and are potentially less certain. Therefore, to the extent that quality revelation is typified by a long lag, signals that emphasize future profits are less attractive to the high-quality seller. Signals that are cost free but do not yield current profits (e.g., warranties) should be preferred, because low-quality firms cannot mimic such signals easily.

(2) What are the cost disparities between high- and low-quality sellers? The relative cost advantage enjoyed by the low-quality firm will influence the choice of signal. When the low-quality firm's costs are considerably lower than those of the high-quality firm, the quality-sensitive segment becomes relatively more attractive to such low-quality firms. Consequently, high-quality firms must use signals that deter low-quality firms from signaling falsely. The cost associated with these signals must be sufficiently large to raise the costs of falsely claiming high quality and should also provide profits only after quality information is revealed. Therefore, signals that emphasize future gains from repeat purchase (i.e., default-contingent signals) dominate signals that yield gains from current sales (default-independent signals).

Further Research

We have drawn principally from the analytical modeling literature in economics, as well as from an emergent modeling literature in marketing on slotting allowances (Chu 1992; Lariviere and Padmanabhan 1997), reputation (Chu and Chu 1994), warranties (Padmanabhan and Png 1995), and umbrella branding (Montgomery and Wernerfelt 1992; Wernerfelt 1988). Although this literature is typified by considerable analytical rigor, a strong empirical tradition is lacking.

Empirical validation. The predictions of signaling models have recently begun to receive some empirical scrutiny. In Table 2, we describe the available empirical evidence about marketing signals of product quality, using our typology to classify them. The principal message from Table 2 is that whereas certain types of signals have received a good deal of empirical attention, others remain largely unexplored. For example, there is little empirical research on sale-contingent default-independent signals, such as low introductory prices and slotting allowances. In contrast, considerable empirical attention has been paid to sale-independent default-independent signals, such as advertising. Under the category of default-contingent signals, the role of high prices in signaling quality has received some scrutiny,

TABLE 2
A Sampling of Empirical Signaling Research

Authors	Type of Signal	Context	Findings
Sale-Independent Default-Independent Signals			
Archibald, Haulman, and Moody (1983)	Advertising	Analysis of secondary data correlating actual prices and objective advertising with published ratings of quality.	Advertising signals a better buy after quality ratings are published.
Caves and Greene (1996)	Advertising and high price	Analysis of secondary data correlating actual prices and advertising outlays with *Consumer Reports* ratings of quality.	Advertising is a source of information rather than a signal of quality. Price is a signal of quality for convenience goods.
Erdem (1998)	Umbrella branding	Analysis of scanner panel data for toothpaste and toothbrushes.	Umbrella brand extensions are expected to have the quality of the parent brand. Low-quality extensions have negative spillover effects on the parent brand.
Erdem and Swait (1998)	Brand name/equity	Survey data from undergraduate students analyzed by LISREL for two categories (jeans and juice).	The consistency and clarity of the brand signal are positively related to signal credibility. Signal credibility is positively related to perceived quality.
Kirmani and Wright (1989)	Advertising	Multiple experiments using university staff as subjects.	High-advertising expense leads to higher quality perceptions, but this belief can be undermined.
Kirmani (1990)	Advertising	Experiment manipulating advertisement size with university staff as subjects.	High-advertising expenditure and quality perceptions display an inverted U relationship as extremely high levels of expenditure suggest that the firm is desperate.
Kirmani (1997)	Advertising	Experiment varying ad repetition and color using student subjects.	There is an inverted U relationship between repetition and perceived quality for color but not black-and-white advertisements.
Mizuno and Odagiri (1989)	Advertising	Computer simulation.	Signaling predictions hold in the presence of consumer learning.
Rotfeld and Rotzoll (1976)	Advertising	Analysis of secondary data correlating actual advertising outlays with published ratings of quality.	Advertising is correlated with quality when the sample contains all brands but not when the sample contains only nationally advertised brands.
Sale-Contingent Default-Independent Signals			
Dawar and Sarvary (1997)	Low introductory price	Experiment manipulating separating, pooling, and ambiguous equilibria with low and high introductory prices using student subjects.	Purchase intentions are consistent with signaling theory, but quality judgments are not.
Rao and Mahi (2000)	Slotting allowances	Survey of grocery store buyers' tendency to charge slotting allowances for stocking new products.	Slotting allowances do not signal manufacturers' confidence in new product demand but are charged by large retailers to relatively small manufacturers.
Revenue-Risking Default-Contingent Signals			
Gerstner (1985)	High price	Analysis of secondary data correlating product category prices with *Consumer Reports* ratings.	Price–quality correlations vary considerably across product categories.
Rao, Qu, and Ruekert (1999)	Brand names	Multiple experiments on mall-intercept shoppers' perceptions in a brand alliance context.	Brands can signal quality on the basis of their investments in reputation as well as their vulnerability to future sanctions, even when they lack a reputation.

TABLE 2
Continued

Authors	Type of Signal	Context	Findings
Tellis and Wernerfelt (1987)	High price	Meta-analysis of existing studies that report price–quality correlations.	Price–quality correlations tend to be higher for durable products because consumers are more quality-sensitive for such products.
Cost-Risking Default-Contingent Signals			
Boulding and Kirmani (1993)	Warranties	Three-factor experimental test of the impact of warranties for reputable and reputation-less computers on MBA student sample.	Warranties signal unobservable quality when they are enforceable.
Kelley (1988)	Warranties	Analysis of secondary data correlating warranties with *Consumer Reports* ratings of quality.	Warranties are positively correlated with quality.
Wiener (1985)	Warranties	Analysis of secondary data correlating warranties with *Consumer Reports* ratings of quality.	Warranties are an accurate signal of product reliability.

though the evidence is largely correlational (Gerstner 1985; Tellis and Wernerfelt 1987). Finally, empirical support for the use of default-contingent cost-risking signals has focused primarily on warranties. Little evidence is available on money-back guarantees or the role of warranties in the presence of consumer moral hazard.

On the basis of the literature summarized in Table 2, we offer four major suggestions for further research in the signaling area. First, there is a need for primary empirical evidence on sale-contingent default-independent signals (e.g., low introductory price, coupons, slotting allowances). Second, there is a need for empirical evidence on several other default-independent signals that involve up-front expenditures and are relevant to marketing practice, such as plush carpeting and decor, store location, retailer reputation, and quality of salespeople. Third, although many of the analytical signaling models incorporate more than one signal (e.g., Milgrom and Roberts [1986] discuss the role of price and advertising), empirical research on consumer responses to multiple signals is sparse. Our typology suggests that combining signals from different categories is perhaps more appropriate than combining signals from the same category. Such combinations enable the seller to benefit from using the entire set of properties that belongs to complementary signals rather than duplicate the same property by using multiple signals that are substitutes. Moreover, research could examine several other issues, such as whether signals operate in an additive or multiplicative fashion, whether a firm may communicate too many different signals and cause information overload, and whether there is an optimal number of signals. Furthermore, because many signals are received by audiences other than those for whom the signal is intended, a signal may have unintended (though desirable) consequences. For example, a signal may provide information to current and potential competitors about a firm's strategy, a topic that has received some attention in the marketing literature (Heil and Langvardt 1994). Fourth, research on the boundary conditions for signaling is warranted. This includes general conditions for signaling as well as conditions for the use of a particular type of signal. In particular, the prescriptions offered in the Managerial Implications section could be rephrased as testable theoretical propositions. For example, tests of the implications of (1) consumer moral hazard, (2) the profitability of the quality-sensitive segment, and (3) the cash availability to the firm on the ability to signal and choice of signal are subsets of seemingly interesting research issues. Addressing these issues by examining consumer perceptions and the firm's incentives simultaneously may lead to a richer understanding of marketplace phenomena.

Appendix

The payoffs for the two types of firms (high- and low-quality) from signaling and not signaling are described here. Because this analysis is intended to be illustrative rather than exhaustive, we make several simplifying assumptions for expository convenience.

Assumptions

1. Assume two firms whose quality (high and low) is exogenously endowed.
2. Assume two segments of buyers with different, stable tastes for quality (high and low).
3. Assume that quality-sensitive buyers will enter only when a firm signals.
4. Assume that there is vicarious learning between segments only when quality-sensitive buyers enter the market and observe the quality of their purchases as well as the purchases from the other firm by other buyers.
5. Assume that though quality is unobservable initially, quality is fully and unambiguously revealed after consumption in the first period.

Notation

p_l and p_h are the prices charged by the low-quality and high-quality firms,

mc_l and mc_h are the marginal costs of producing low and high quality,

q_l and q_h are the quantities sold to the quality-insensitive and quality-sensitive segments each period,

n is the number of times the product will be purchased, and

c_s is the cost of the signal.

Payoffs

There are four possible scenarios:

First, the high-quality firm signals and the low-quality firm does not (i.e, cells A and D in our schematic). In Cell A, the high-quality firm's payoff is

$$(1) \qquad (p_h - mc_h) \times q_h \times n - c_s.$$

In Cell D, the low-quality firm's payoff is

$$(2) \qquad (p_l - mc_l) \times q_l \times n.$$

Here, the two firms cater to differentially quality-sensitive buyers with products of differing quality.

Second, neither firm signals (i.e., cells B and D in our schematic). In Cell B, the high-quality firm's payoff is

$$(3) \qquad (p_h - mc_h) \times \tfrac{1}{2}(q_l) \times n.$$

In Cell D, the low-quality firm's payoff is

$$(4) \qquad (p_l - mc_l) \times \tfrac{1}{2}(q_l) \times n.$$

Here, because neither the high- nor the low-quality firm is signaling, we simply assume that the two firms share the entire market for quality-insensitive buyers equally. By Assumptions 3 and 4, quality-sensitive buyers are not in the market and therefore do not learn about quality.

Third, the high-quality firm does not signal, and the low-quality firm falsely signals (i.e., Cells B and C in our schematic). In Cell B, the high-quality firm's payoff is

$$(5) \qquad (p_h - mc_h) \times (q_l) + (p_h - mc_h) \times (q_h) \times (n - 1) = (p_h - mc_h) \times [q_l + q_h \times (n - 1)].$$

In Cell C, the low-quality firm's payoff is

$$(6) \qquad (p_l - mc_l) \times q_h - c_s + (p_l - mc_l) \times q_l \times (n - 1) = (p_l - mc_l) \times [q_h + q_l \times (n - 1)] - c_s.$$

In the first period, all quality-sensitive buyers purchase from the low-quality firm, and vice versa. After both firms' true quality is revealed, the high-quality firm will acquire all quality-sensitive buyers, and the low-quality firm will acquire all quality-insensitive buyers.

Fourth, both firms signal (i.e., Cells A and C in our schematic). In Cell A, the high-quality firm's payoff is

$$(7) \qquad (p_h - mc_h) \times \tfrac{1}{2}q_h - c_s + (p_h - mc_h) \times q_h(n - 1) = (p_h - mc_h) \times [\tfrac{1}{2}q_h + q_h (n - 1)] - c_s.$$

In Cell C, the low-quality firm's payoff is

$$(8) \qquad (p_l - mc_l) \times \tfrac{1}{2}q_h - c_s + (p_l - mc_l) \times q_l \times (n - 1) = (p_l - mc_l) \times [\tfrac{1}{2}q_h + q_l \times (n - 1)] - c_s.$$

Here, the quality-sensitive market is initially shared by both firms, but when quality is revealed, the high-quality firm acquires all quality-sensitive customers and the low-quality firm caters only to quality-insensitive customers.

Conditions for a Separating Equilibrium

Here, the low-quality firm should choose not to signal, which will occur when D > C:

$$(9a) \quad (p_l - mc_l) \times \tfrac{1}{2}(q_l) \times n > (p_l - mc_l) \times [q_h + q_l \times (n - 1)] - c_s,$$

which reduces to

$$(9b) \qquad c_s > (p_l - mc_l) \times [q_h + (n - 2)(\tfrac{1}{2}q_l)].$$

In Equation 9, the left-hand side is the smaller of Equations 2 and 4, and the right-hand side is the larger of Equations 6 and 8. This condition specifies the most restrictive circumstance for when the gains from not signaling dominate the gains from signaling falsely.

In addition, the high-quality firm should choose *to* signal, which will occur when A > B. Although it is clear that Equation 7 is smaller than Equation 1, whether Equation 3 or Equation 5 is greater depends on the relative sizes of the quality-sensitive segment and the quality-insensitive segment. Consequently, the condition can be stated as

$$(10a) \quad (p_h - mc_h) \times [\tfrac{1}{2}q_h + q_h(n - 1)] - c_s > (p_h - mc_h) \times \tfrac{1}{2}(q_l) \times n,$$

which reduces to

$$(10b) \qquad (p_h - mc_h) \times [q_h(2n - 1)/2 - \tfrac{1}{2}q_l \times n] > c_s,$$

or

$$(10c) \quad (p_h - mc_h) \times [\tfrac{1}{2}q_h + q_h (n - 1)] - c_s > (p_h - mc_h) \times [q_l + q_h \times (n - 1)],$$

which reduces to

$$(10d) \qquad (p_h - mc_h) \times (\tfrac{1}{2}q_h - q_l) > c_s.$$

A little algebra shows that Equation 10b applies if $\tfrac{1}{2}q_l(n - 2) > q_h(n - 1)$; otherwise Equation 10d applies.

Conditions for a Pooling Equilibrium

The basic argument is captured in a simple reversal of the conditions for a separating equilibrium described previously, that is, if B > A, or C > D. If either of these conditions prevails, the signal will be valueless. Specifically,

$$(11) \qquad (p_l - mc_l) \times [q_h + (n - 2)(\tfrac{1}{2}q_l)] > c_s$$

indicates that the payoffs from C (falsely signaling) exceed the payoffs from D, because the cost of the signal (c_s) is relatively low for the low-quality firm.

Alternatively,

$$(12a) \qquad (p_h - mc_h) \times [q_h(2n - 1)/2 - \tfrac{1}{2}q_l \times n] < c_s,$$

or

$$(12b) \qquad (p_h - mc_h) \times (\tfrac{1}{2}q_h - q_l) < c_s,$$

indicates that the payoffs from B (not signaling) exceed the payoffs from A, because the cost of the signal is relatively high for the high-quality firm. Again, whether Equation 12a or Equation 12b applies will depend on whether $\tfrac{1}{2}q_l(n - 2) > q_h(n - 1)$.

In summary, if either Equation 11 or the relevant one of Equations 12a and 12b applies, a pooling equilibrium will occur.

Size of Bond

The size of c_s is important in determining whether a separating equilibrium is obtained. c_s needs to be sufficiently large that the low-quality firm shies away from false signals and sufficiently small that the high-quality firm will engage in the expenditure. In other words, from Equations 9a, 10b, and 10d,

$$(13a)\quad (p_h - mc_h) \times [q_h(2n-1)/2 - \tfrac{1}{2}q_l \times n] > c_s > (p_l - mc_l) \times [q_h + (n-2)(\tfrac{1}{2}q_l)],$$

or

$$(13b)\quad (p_h - mc_h) \times (\tfrac{1}{2}q_h - q_l) > c_s > (p_l - mc_l) \times [q_h + (n-2)(\tfrac{1}{2}q_l)],$$

depending, as discussed previously, on whether $\tfrac{1}{2}q_l(n-2) > q_h(n-1)$.

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