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Quality testing and disclosure

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and

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Sellers are often more able than consumers to test product quality. We show that whether such firms will voluntarily test quality and disclose what they learn depends in a paradoxical way upon the presence of mandatory disclosure rules: only if disclosure is mandatory will a seller not test and disclose. We then ask whether it is even desirable for consumers to be informed about quality at the time they purchase. We show that if information about product quality can be obtained only after all production decisions have been made, and if income effects are negligible, then consumers and firms will agree that a regime in which consumers are uninformed (informed) is preferable to a regime in which they are informed (uninformed) if income and quality are complements (substitutes) in utility. Consumers and firms can disagree—in either way—about which regime is better if income effects are not negligible. We conclude by discussing the desirability of mandatory testing laws.

1. Introduction

Much attention has been given to the consequences of sellers' having better information than prospective buyers about product quality. In contrast, the consequences of sellers' having better access to information have not been studied. A seller has better access to information when he is better able to test his products, which is the case when consumers do not know what tests are available, or when they lack the expertise to administer and to interpret tests, or when they cannot purchase enough units to obtain statistical significance. Testing by private experts, such as Consumers Union, which then publishes the results is often infeasible, both because outside experts may not have the testing expertise of inside experts, and because the free-rider problem can undermine markets for information. We ask in this article whether sellers will voluntarily test quality and inform consumers of what they learn, and whether it is desirable for consumers to be so informed.

When testing is not an issue, both the market and the government can provide informed sellers with incentives to communicate. The most basic incentives are to be truthful, i.e.,

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not to lie or to misrepresent products. Competition may reward a firm that periodically brings out new products with a reputation for honesty; customers who have been misled should take their future business to a more honest vender. The government provides incentives to be truthful by enacting antifraud laws, such as those regarding false advertising, perjury, and warranties of fitness. For an antifraud law to be effective, there must be a way to establish *ex post* the veracity of the seller. This is accomplished most directly when a buyer observes, and can verify to a third party, the true quality of a product at some time after purchasing it. Even if buyers cannot observe quality *ex post*, antifraud laws may be obeyed if experts can be hired to determine why a product failed, or if auditors and lawyers can be hired to study the records of an accused firm. We shall assume that for whatever reason, sellers will not lie.

The flow of information from sellers to buyers is enhanced more not only if sellers are honest, but also if they disclose everything relevant that they know. An example of a government-provided incentive to disclose is a mandatory disclosure law, such as is prevalent in securities markets. A less obvious example is the common law practice of awarding greater damages to plaintiffs in product liability cases when it is discovered that the seller had secretly known of design flaws. The intent in both cases is to cause a seller to expect to pay a penalty in the event of product failure unless he had fully revealed his knowledge of possible defects. As long as there is positive probability that the information held by a seller can be discovered *ex post*, the penalties for not disclosing can be made large enough to make full disclosure optimal. For lack of a better term, we shall refer to all government-provided incentives to disclose as disclosure rules.

The market also can provide incentives for informed sellers to disclose. An argument for this when there are many sellers appears in Stiglitz (1975) and Jovanovic (1983). It is more surprising, although the argument is similar, that the market can induce even a monopolist to disclose. The argument for this is due to Grossman (1981), Milgrom (1981), and Milgrom and Roberts (1984), who consider a "game of persuasion" in which the strategy of the seller is to reveal information to the buyers. Although the seller cannot lie because of the presence of effective antifraud laws, he can be vague, up to claiming total ignorance. The seller would like to increase his demand by convincing buyers that quality is high. Buyers will therefore assume the worst—any vague claim about product quality will be interpreted as revealing that the true quality is at the lowest level consistent with the claim's being truthful. The seller responds to this skepticism by precisely disclosing the true quality.

We, too, consider a game of persuasion involving a monopoly seller. Our model differs primarily in that the seller is not assumed to be exogenously informed of product quality, but must instead decide whether to acquire such information. We make the extreme assumption that the seller has available a costless test that will fully reveal quality. The fact that testing is costless, as well as that we have only one seller, distinguishes the model from that of Farrell and Sobel (1983) and Farrell (1984). Our model also differs from the others by its generality: we leave unspecified everything that is irrelevant, which includes the number of buyers, their payoff functions, and their strategies.

Even though testing is costless, it is easy to see that the seller may not be forced by buyer skepticism to test quality voluntarily. For example, suppose the seller can make it *verifiably* known before the market opens that he has not tested quality. Then the seller can decide not to test without causing consumers to disbelieve him when he claims to be ignorant. If the seller is driven to disclose when he does test, and if the profits obtained when buyers are ignorant exceed the expected profits obtained when they are informed, he will not test.

In Section 2 we consider the more realistic case in which consumers cannot know for sure that the seller has not tested quality. Whether the market provides incentives for the seller to test then depends upon whether disclosure rules are effective. The dependence is, we believe, counterintuitive and perverse. The seller will test and fully disclose if disclosure rules are *not* in effect. If disclosure rules are in effect, the seller will not test (and therefore
not disclose) whenever he prefers buyers to be uninformed. The intuition for the second result is that when disclosure rules are effective, the seller can claim ignorance only if he has not tested; a claim of ignorance then must be taken at face value. Thus, Section 2 concludes with the observation that a monopolist will not necessarily test and inform buyers of product quality.

In Section 3 we ask, in the context of a more detailed model, whether it is even desirable for consumers to be informed. The type of product we consider in this section is not one that creates a significant hazard if its quality is low, for which the answer is obvious. Rather, we consider a product that is put to the same use regardless of its quality—only its effectiveness or operating cost in that use depends upon its quality. Some examples might be a software package whose job-specific effectiveness is in doubt, an air conditioning design whose efficiency is in doubt, a financial security whose return is in doubt, or a demonstrably safe drug intended to cure cancer (Laetrile?) whose efficacy is in doubt. For such products it is not clear that welfare is greatest in a regime where consumers are informed before they purchase. Releasing quality information will only cause the price of a product to be positively correlated with its quality.

A well-known result regarding the welfare effects of public information is that of Hirschleifer (1971), which is generalized by Marshall (1974). These authors compare a regime characterized by a complete set of contingent claims exchange markets with another regime that differs only by the public announcement of information before the markets open. They find that a competitive equilibrium in the second regime, the one with informed traders, is inefficient because of the uninsurable price risk created by the announcement.

We find instead that in some cases the regime with informed consumers is unanimously preferred by producers and consumers, although in other cases the regime with uninformed consumers is unanimously preferred. Our results differ primarily because we assume, to allow demand to depend on quality, that consumers have state-dependent utility. As Hirschleifer and Riley (1979) note, demand for insurance at an actuarily fair price can be negative if utility is state dependent. Public information cannot then be shown to be undesirable simply because it creates an uninsurable price risk.

Which regime is better depends in part upon whether income and quality are substitutes or complements in utility. One assumption we consider is that utility is quasi-linear, so that income effects are zero. In this case we show that the regime with informed consumers is Pareto superior to the regime with uninformed consumers if quality and income are substitutes, whereas it is Pareto inferior if they are complements. The intuition is straightforward. If quality and income are substitutes, consumers would like to consume relatively more income in states where quality is low. This is what happens when they are informed, since then the price of the product is lower when it has low quality. On the other hand, if quality and income are complements, consumers would prefer to have more income in high quality states than in low quality states, which is the opposite of what happens when they are informed.

This intuition can be overturned when utility is not quasi-linear. We end Section 3 with two examples showing that then producers and consumers can disagree in each of the two possible ways about which regime is better. Thus, all four possibilities can occur for agreement and disagreement between consumers and producers.

We conclude in Section 4 with a brief discussion of the desirability of mandatory testing laws. We show in the Appendix that the model in Section 2 is a reduced form of that in Section 3.

2. Voluntary testing and disclosure

In this section we construct a model of the firm to address the question of whether firms will voluntarily test and disclose product quality. We assume that testing is costless and surely determines the true quality to make the results as sharp as possible. We also assume
that the firm tests secretly, so that consumers cannot know whether the firm knows the quality at the time they purchase.

The model is in the spirit of the "games of persuasion" studied by Grossman (1981), Milgrom (1981), and Milgrom and Roberts (1984). The equilibrium is in the spirit of Kreps and Wilson's (1982) sequential equilibrium. Instead of defining a game between the firm and consumers, however, we define in this section only a "reduced-form game" that is more in the tradition of partial equilibrium models of the firm. The model specifies only how the firm's profit depends on the probability beliefs of consumers about quality, and how the consumers change those beliefs when the firm makes various claims about quality. Left unspecified are the objectives and actions of consumers, and the decisions of the firm other than its testing and announcement decisions. As is shown in the Appendix, the reduced-form game defined here is consistent with a game in which the firm is a monopoly price-setter and the consumers maximize expected utility on the basis of probabilities that are influenced by what the firm claims about quality.

The set of states of nature that determine quality is \( Q = \{1, \ldots, S\} \). The interpretation will be that states are numbered so that quality increases with the state; we shall sometimes refer to a state as a quality level. The initial beliefs of both the firm and the consumers are specified by a probability vector \( \phi = (\phi_1, \ldots, \phi_S) \), where each \( \phi_s \) is positive.

Let \( e_s \) be the probability vector putting all probability on state \( s \). The firm's profit is given by a function \( \pi(\gamma) \) of the beliefs of consumers at the time they purchase, \( \gamma = (\gamma_1, \ldots, \gamma_S) \). The central assumption is that the firm wants consumers to believe quality is high. We could capture this by assuming that \( \pi(\gamma) \) increases when \( \gamma \) increases in the sense of stochastic dominance. Instead, we make the weaker assumption that if two probability vectors are ordered by stochastic dominance, and if one of them puts all probability on one state, then the corresponding profit levels have the same ordering:

\[
\pi(e_s) \begin{cases}
< \pi(\gamma) & \text{if } \sum_{t<s} \gamma_t = 0 \\
> \pi(\gamma) & \text{if } \sum_{t>s} \gamma_t = 0,
\end{cases}
\text{ for any } \gamma \text{ and } e_s \neq e_s. \tag{1}
\]

Note that (1) implies that \( \pi(e_s) < \pi(e_{s+1}) \) and that \( \pi(\gamma) < \pi(e_S) \) for all \( \gamma \neq e_S \).

The firm has two decisions to make: first, whether to test the product, and second, what to claim about its quality. The possibility of acquiring information in this model is what distinguishes it from that of Grossman (1981), Milgrom (1981), and Milgrom and Roberts (1984). We follow these authors by viewing the firm's second decision, what to announce about quality, as identifying a subset of quality levels in which the true quality lies. The firm will be truthful because of the presence of effective antifraud incentives. Hence, to avoid even a chance of being caught in a lie, the firm must report total ignorance if it does not test, which we view formally as reporting the set \( A = Q \). If it does test, to avoid lying the firm must report a superset of the true quality level. The firm can report according to a mixed strategy, which allows the firm to be as vague as possible.

Thus, a behavioral strategy for the firm is a pair \((\alpha, \beta)\), where \( \alpha \) is the probability of testing and \( \beta \) is a conditional probability function that determines announcements when the firm tests: if the firm tests quality and learns that the true state is \( s \), then \( \beta(A|s) \) is the probability it reports \( A \subseteq Q \). The strategy \((\alpha, \beta)\) is feasible in the game without disclosure rules if and only if it satisfies

\[
0 \leq \alpha \leq 1; \tag{2a}
\]

\[
\beta(\cdot|\cdot) \geq 0 \quad \text{and} \quad \sum_{A \subseteq Q} \beta(A|s) = 1 \text{ for all } s \in Q; \quad \text{and} \tag{2b}
\]

\[
\beta(A|s) = 0 \text{ for all } A \subseteq Q \text{ and } s \not\in A. \tag{2c}
\]
Conditions (2a) and (2b) require that \( \alpha \) and \( \beta \) be probability functions. Condition (2c) requires the firm to report a superset of the true state when it tests, which reflects the effectiveness of antifraud laws.

Consumers will update their beliefs about quality when they hear an announcement by the firm. Their rule for updating is given by an inference function

\[
\gamma(A) = (\gamma(1|A), \ldots, \gamma(S|A)),
\]

where \( \gamma(s|A) \) is the probability put on state \( s \) when the firm reports subset \( A \). An inference function is feasible if and only if it satisfies the laws of probability:

\[
\gamma(\cdot|\cdot) \geq 0 \quad \text{and} \quad \sum_{s \in Q} \gamma(s|A) = 1 \text{ for all } A \subseteq Q. \tag{3}
\]

For \((\alpha, \beta, \gamma)\) to be an equilibrium, we require \( \gamma \) to be a rational response to \((\alpha, \beta)\) in the sense of Kreps and Wilson (1982). That is, \( \gamma \) must be consistent with both Bayes' rule and with the fact that the firm can only report supersets of the truth. Equilibrium therefore requires

\[
\gamma(s|Q) = \frac{\phi_s [\alpha \beta(Q|s) + 1 - \alpha]}{\alpha \sum_{t \in Q} \phi_t \beta(Q|t) + 1 - \alpha} \quad \text{if} \quad \alpha \sum_{t \in Q} \phi_t \beta(Q|t) + 1 - \alpha > 0; \tag{4a}
\]

\[
\gamma(s|A) = \frac{\phi_s \beta(A|s)}{\sum_{t \in Q} \phi_t \beta(A|t)} \quad \text{if} \quad A \neq Q \quad \text{and} \quad \sum_{t \in Q} \phi_t \beta(A|t) > 0; \quad \text{and} \tag{4b}
\]

\[
\gamma(s|A) = 0 \text{ for all } A \subseteq Q \text{ and } s \notin A. \tag{4c}
\]

Conditions (4a) and (4b) are merely Bayes' rule for updating when the firm announces either total ignorance, \( A = Q \), or a more informative report, \( A \subset Q \). Both conditions reflect the antifraud requirement that the firm must report total ignorance when it does not test. Condition (4c) requires that \( \gamma \) be consistent with the restriction (2c) that the firm can only report supersets of the truth. Note that (4c) applies even to subsets \( A \) that have zero probability of being reported according to \((\alpha, \beta)\).

If the adopted strategies are \((\alpha, \beta, \gamma)\), the firm's expected profit is

\[
\Pi(\alpha, \beta, \gamma) = \alpha \sum_{s \in Q} \sum_{A \subseteq Q} \phi_s \beta(A|s) \pi(\gamma(A)) + (1 - \alpha) \pi(\gamma(Q)),
\]

where the last term follows because the firm must report \( Q \) when it does not test. A **sequential equilibrium without disclosure rules** is a triple \((\alpha, \beta, \gamma)\) that satisfies the feasibility conditions (2) and (3), the consumer rationality condition (4), and the firm rationality condition,

\[
\Pi(\alpha, \beta, \gamma) \geq \Pi(\hat{\alpha}, \hat{\beta}, \hat{\gamma}) \text{ for all } (\hat{\alpha}, \hat{\beta}) \text{ satisfying (2).} \tag{5}
\]

The surely testing, truthfully disclosing, and skeptically inferring strategies are \( \alpha = 1 \), \( \beta(s|s) = 1 \), and \( \gamma(m(A)|A) = 1 \), where \( m(A) \) is the minimum quality level in the set \( A \). The skeptical inference rule is obviously a rational response to the truthful disclosing strategy, and truthful disclosing is obviously the best the firm can do when consumers are so skeptical. Their skepticism also makes testing optimal for the firm because the firm must report total ignorance if it does not test, thereby causing consumers to believe the quality level is the worst possible, even when it is not. Testing, together with truthful reporting, dispels this most pessimistic of beliefs whenever it is unwarranted. Thus, these strategies constitute a sequential equilibrium without disclosure rules. The following proposition characterizes all such equilibria.

**Proposition 1.** Any \((\alpha, \beta, \gamma)\) satisfying (2) and (3) is a sequential equilibrium without disclosure rules if and only if (i) \( \alpha = 1 \); (ii) \( \beta(A|s) > 0 \) implies \( s = m(A) \); and (iii) \( \gamma(m(A)|A) = 1 \) for all \( A \subseteq Q \).
Proof. We show only the necessity of (i)–(iii); the proof of sufficiency is straightforward. So let \((\alpha, \beta, \gamma)\) be an equilibrium.

(i) Suppose \(\alpha < 1\). Then there is positive probability that \(Q\) is reported and the true state is not \(S\). Hence, \(\gamma(S|Q) < 1\) (see (4a)). Therefore, (1) implies \(\pi(\gamma(Q)) < \pi(e_3)\), so that expected profit conditional on \(S\) is less than \(\pi(e_3)\):

\[
\Pi(\alpha, \beta, \gamma|S) = \alpha \sum_{A \subseteq Q} \pi(\gamma(A))\beta(A|S) + (1 - \alpha)\pi(\gamma(Q)) < \alpha \sum_{A \subseteq Q} \pi(e_3)\beta(A|S) + (1 - \alpha)\pi(e_3) = \pi(e_3).
\]

But the firm could obtain \(\pi(e_3)\) in state \(S\) by testing for sure and announcing \(A = \{S\}\) whenever \(S\) is the true state. Because it does not have to disclose, the firm need not alter its reporting strategy in other states. This yields a new strategy that is feasible and increases expected profit, a contradiction.

(ii) We first show that for a given \(A\), \(\beta(A|s) > 0\) for at most one \(s\). Assuming not, let \(t\) be the largest state such that \(\beta(A|t) > 0\), and let \(s < t\) be another state such that \(\beta(A|s) > 0\). Then (4b) implies \(\gamma(t|A) < 1\). Since \(\beta(A|w) = 0\) for \(w > t\), (4b) also implies that \(\gamma(w|A) = 0\) for all \(w > t\). Hence, \(e_t\) stochastically dominates \(\gamma(A)\). The firm could thus do better by reporting \(\{t\}\) instead of \(A\) if the state is \(t\), contradicting \(\beta(A|t) > 0\).

Now, assume \(\beta(A|s) > 0\) for some \(s \neq m(A)\). Since \(s\) is the only state in which \(A\) is reported with positive probability, \(\gamma(A) = e_s\) (see 4b)). Similarly, letting \(B \subseteq Q\) be a set such that \(\beta(B|m(A)) > 0\), \(\gamma(B) = e_{m(A)}\). But \(e_s\) stochastically dominates \(e_{m(A)}\), so that the firm could do better by announcing \(A\) and never announcing \(B\) when it learns the state is \(m(A)\).

This contradiction proves (ii).

(iii) Suppose \(\gamma(m(A)|A) < 1\) for some \(A \subseteq Q\). As in the previous paragraph, if we let \(B \subseteq Q\) be a set such that \(\beta(B|m(A)) > 0\), then \(\gamma(B) = e_{m(A)}\). But, since \(\gamma(m(A)|A) < 1\), (4c) implies that \(\gamma(A)\) stochastically dominates \(e_{m(A)}\). Hence, the firm should never announce \(B\) if the state is \(m(A)\), a contradiction. \(Q.E.D.\)

Proposition 1 implies that antifraud incentives alone, without the addition of disclosure rules, will cause consumers to be so skeptical that the firm will be forced to test fully and to disclose. Disclosure is full in the sense that consumers are able to "invert" the firm's reporting strategy to determine the true quality level, since no announcement will be made with positive probability in more than one state. Given that the seller will surely test, the full disclosure result is in accord with Milgrom's (1981) demonstration that any sequential equilibrium with an exogenously informed seller must involve full disclosure. The complete characterization of equilibrium reporting and inference rules in (ii) and (iii) is more similar to the characterization in Proposition 1 of Milgrom and Roberts (1984), where the difference again is that they specify a particular game and assume that the seller is exogenously informed about quality.

The situation is different when effective disclosure rules are present. We take a disclosure rule, as discussed in the Introduction, to be an incentive for the firm to reveal fully its information about quality. The presence of effective disclosure rules simply restricts further the definition of a feasible strategy for the firm. We say \((\alpha, \beta)\) is feasible in the game with disclosure rules if and only if it satisfies

\[
0 \leq \alpha \leq 1, \quad \text{and} \quad \beta(A|s) = \begin{cases} 0 & \text{if } A \neq \{s\} \\ 1 & \text{if } A = \{s\}. \end{cases}
\]

Condition \((2a')\) is the same as \((2a)\), whereas \((2b')\) strengthens \((2b)\) and \((2c)\) to require that the firm fully disclose the state when it tests.
An inference function remains feasible provided it satisfies (3), the rules of probability. It is a rational response to any \((\alpha, \beta)\) satisfying (2') provided it satisfies

\[
\gamma(s|Q) = \phi_s \text{ for all } s \in Q, \quad \text{and} \quad \gamma(s\{s\}) = 1 \text{ for all } s \in Q. \tag{4a'} \tag{4b'}
\]

Condition (4a') reflects knowledge of the effectiveness of disclosure rules. Because it is known that the firm must fully disclose when it tests, an announcement of total ignorance must mean the firm did not test, so that consumers should not infer anything from such an announcement. Condition (4b') is a weaker version of (4c), and it merely reflects one effect of antifraud laws, namely, any announcement of a precise quality must be the truth. This minimal rationality requirement is all that is required.

The following proposition characterizes the sequential equilibria with disclosure rules, which are triples \((\alpha, \beta, \gamma)\) satisfying (2'), (3), (4'), and

\[
\Pi(\alpha, \beta, \gamma) \geq \pi(\hat{\alpha}, \hat{\beta}, \gamma) \text{ for all } (\hat{\alpha}, \hat{\beta}) \text{ satisfying (2').} \tag{5'}
\]

**Proposition 2.** Any \((\alpha, \beta, \gamma)\) satisfying (2') and (3) is a sequential equilibrium with disclosure rules if and only if

\[
\alpha = \begin{cases} 
0 & \text{if } \pi(\phi) > \sum_{s \in Q} \phi_s \pi(e_s) \\
1 & \text{if } \pi(\phi) < \sum_{s \in Q} \phi_s \pi(e_s). 
\end{cases}
\]

**Proof.** Since \(\beta\) specifies full disclosure, expected profit at \((\alpha, \beta, \gamma)\) is

\[
\Pi(\alpha, \beta, \gamma) = \alpha \sum_{s \in Q} \phi_s \pi(e_s) + (1 - \alpha)\pi(\gamma(Q)).
\]

Since (4a') implies that no updating occurs if \(Q\) is announced, \(\gamma(Q) = \phi\). Hence,

\[
\Pi(\alpha, \beta, \gamma) = \alpha \sum_{s \in Q} \phi_s \pi(e_s) + (1 - \alpha)\pi(\phi).
\]

The firm’s best strategy is thus always to test \((\alpha = 1)\) if \(\sum_{s \in Q} \phi_s \pi(e_s) > \pi(\phi)\), and never to test \((\alpha = 0)\) if \(\sum_{s \in Q} \phi_s \pi(e_s) < \pi(\phi)\). Q.E.D.

Proposition 2 states that when disclosure rules are effective, the firm will not test (and hence not disclose) exactly when it prefers its customers to be uninformed rather than informed. Since without disclosure rules the firm will test and disclose, any change caused by a disclosure rule will be just the opposite of its intent. In any case, in the context of our model, mandatory disclosure laws are exactly what firms that can choose whether to acquire information should want.

When disclosure rules are effective, a firm is not forced to test to dispel skepticism simply because consumers cannot be skeptical: an announcement of ignorance must be taken at face value when it is known that disclosure rules cause the firm to disclose all that it knows. There are other reasons why announcements of ignorance might be credible and hence allow the firm not to test. First, and most obviously, it may be that testing cannot be done without consumers’ observing that it has been done. Second, announcements of ignorance can be credible if testing or disclosing is costly, as is shown in Farrell (1984), Farrell and Sobel (1983), and Jovanovic (1983) in competitive contexts. Third, if test results are not perfectly informative, so that with positive probability testing will reveal no information, then announcements of ignorance would also be credible.

We have not considered the conditions under which disclosure rules would be effective. To do so would involve introducing a third agent with an *ex post* information structure.
who would enforce penalties when discontented customers brought legal action against the firm, somewhat along the lines of Palfrey and Romer (1983). Disclosure rules would then alter the firm’s payoffs instead of its strategy set; the latter was justified here only because we assumed that disclosure rules would be either fully effective or fully ineffective. This extension is beyond the scope of this article. We conjecture, however, that it would yield the following result: if a disclosure rule could be effective, then even without it the firm will test and disclose if and only if it prefers to have its customers informed. The logic for this is that a disclosure rule could be effective only if the third party can determine ex post whether the firm had tested. But then, the firm should be able to sign, and make public, a binding contract to the effect that it will pay a large penalty if it claims ignorance but the third party discovers it had tested quality. This would serve to make its announcements of ignorance credible even in the absence of disclosure rules, and thus gives us another situation in which the firm would not necessarily test and disclose.

3. Welfare comparisons

We turn now to the welfare consequences of informing consumers about quality, which require a more detailed description of firm and consumer preferences. We compare a market regime in which consumers are informed with one in which they are uninformed and do not specify now why information is communicated in one regime but not in the other. Both regimes have only the product market; neither regime has an insurance market allowing income to be shifted from one state to another. The most straightforward interpretation is that the environment is one in which the firm could, but for some reason does not, voluntarily test and disclose. The regime with informed consumers then differs from the regime with uninformed consumers by the presence of a mandatory testing and disclosing law. We show in the Appendix that the model in this section reduces to that in Section 2 under this interpretation.

We consider a single firm that produces a new product with uncertain quality. The firm is assumed to be a price-setting monopoly. The results in this section also hold if the firm is assumed to be a price-taker, as is shown in Matthews and Postlewaite (1984). This competitive assumption would be appropriate if there were actually many firms producing the good, and in each state every unit of the good has the same quality regardless of which firm produced it. For example, consider an unpatented drug like Laetrile, or a dietary supplement, that can be produced by many firms. Nevertheless, the monopoly case seems more compelling, particularly since the results in the previous section were derived under the assumption that only one firm could acquire information about quality.

The product with uncertain quality is denoted by $x$. Good $y$ is money, or rather, a composite representing expenditure on all other goods. We assume for simplicity that there is one, representative consumer. She has an endowment $Y$ of money and no endowment of $x$. Because the benefit she obtains from a consumption bundle $(x, y)$ depends on the quality of $x$, we assume the consumer has a state-dependent utility function $u^s(x, y)$. Her ex ante preferences over contingent commodity bundles $\{(x_s, y_s)\}_{s=1,S}$ are represented by the expected utility $EU^s(x_s, y_s) = \sum \phi_s u^s(x_s, y_s)$. To capture the notion that quality varies positively with the state, our basic assumption is that the marginal rate of substitution of $y$ for $x$ increases in $s$: $u^s_1/u^s_2 < u^{s+1}_1/u^{s+1}_2$ for all $s = 1, \ldots, S - 1$. (6)

This assumption will imply that the consumer’s demand for $x$ increases in $s$ if she is informed. We also assume that for every probability vector $\hat{\gamma}$, the function $\sum \hat{\gamma}_s u^s(x, y_s)$ is twice continuously differentiable and strictly quasi-concave in $(x, y_1, \ldots, y_S)$, with each $u^s_1 > 0$ and $u^s_2 > 0$.

In the uninformed consumer regime, the consumer is not informed about quality at the time she purchases. Given a price $p$ for $x$, her maximization problem is simply
\[
\begin{align*}
\text{Max } Eu^I(x, y) \text{ subject to } px + y & \leq Y. \quad (7)
\end{align*}
\]

We shall assume she purchases positive amounts of both goods, so that the inverse demand function in this regime, \( p_t(x) \), satisfies
\[
\begin{align*}
p_t(x) &= \frac{Eu^I_t(x, Y - p_t(x)x)}{Eu^I_2(x, Y - p_t(x)x)} \quad (8)
\end{align*}
\]

near the equilibrium. We assume that for any \( x \) near the equilibrium amount, a unique \( p_t(x) \) is defined by (8).

In the informed consumer regime the consumer is informed about the quality of \( x \) at the time she makes the purchase. If she is informed that the state is \( s \) and the price of \( x \) is \( p_s \), her problem is
\[
\begin{align*}
\text{Max } u^I(x, y) \text{ subject to } p_s x + y & \leq Y. \quad (9)
\end{align*}
\]

We shall again assume that all equilibrium quantities are positive, and that inverse demand curves are well defined near the equilibrium by
\[
\begin{align*}
p_s(x) &= \frac{u^I_1(x, Y - p_s(x)x)}{u^I_2(x, Y - p_s(x)x)}. \quad (10)
\end{align*}
\]

The monotonicity property assumed in (6) implies that \( p_1(x) < \ldots < p_S(x) \), as is verified in the Appendix.

Good \( x \) is produced from good \( y \) according to a cost function \( y = c(x) \), which has continuous derivatives \( c' > 0 \) and \( c'' \geq 0 \). The basic technological assumption is that the output decision must be made before anyone knows the true state of nature. This is in keeping with the interpretation that quality information can be collected only by testing a finished product. The firm chooses \( x \) to maximize profits in the uninformed consumer regime. In the informed consumer regime the firm has perfect foresight regarding the inverse demand functions in each state, and it chooses \( x \) to maximize expected profits.

An uninformed consumer equilibrium is a triple \((x^U, y^U, p^U)\) satisfying
\[
\begin{align*}
x^U &\in \arg\max_{x \geq 0} p_t(x)x - c(x); \quad (11) \\
p^U &= p_t(x^U); \quad \text{and} \quad (12) \\
y^U &= Y - p^Ux^U. \quad (13)
\end{align*}
\]

Note that implicit in (12) is an interiority assumption that \( x^U > 0 \), which also implies from (11) that \( p^U = c(x^U) \). An informed consumer equilibrium is a \((2S + 1)\)-tuple \((x^I, (y^I_s, p^I_s)_{s=1}^S)\) satisfying
\[
\begin{align*}
x^I &\in \arg\max_{x \geq 0} (Ep_s)x - c(x); \quad (14) \\
p^I_s &= p_s(x^I) \text{ for all } s; \quad \text{and} \quad (15) \\
y^I_s &= Y - p^I_s x^I \text{ for all } s. \quad (16)
\end{align*}
\]

The consumption of \( x \) in an informed consumer equilibrium does not depend upon the state because the price adjusts to clear the market in every state—demand for \( x \) would be infinite at a zero price because we have assumed \( u^I_1 > 0 \). Since the inverse demand functions are ordered by the state, (15) implies that the prices are ordered \( p^I_1 < \ldots < p^I_S \), and the incomes are ordered \( y^I_1 > \ldots > y^I_S \).

The ex ante welfare comparison of the two regimes depends largely upon how the marginal utility of income varies with the quality of the good. For example, if the marginal utility of income does not vary with quality, the consumer's consumption of income optimally should not depend upon the state. As this is the case in the uninformed consumer
regime, it should not be surprising that the uninformed consumer equilibrium is fully efficient if the function \( u^*_2 \) does not depend on \( s \) and the firm is a competitive price-taker (see Proposition 4 in Matthews and Postlewaite (1984)).

If the marginal utility of income does vary with quality, much depends on whether it increases or decreases with quality. In the former case income and quality are complements in utility, whereas in the latter case they are substitutes. If they are substitutes, and if the consumer had access to perfect insurance markets, she would shift income from high-quality states to low-quality states by purchasing insurance against low quality. This is the direction in which income is shifted in the informed consumer regime, since in an informed consumer equilibrium the price of \( x \) varies positively with the state. There thus seems to be a case for informing the consumer if income and quality are substitutes in utility. If they are complements, the consumer would like to shift income from low- to high-quality states by selling insurance against low quality. As this is the opposite of what occurs in the informed consumer equilibrium, we can conjecture that it is better to keep the consumer uninformed if income and quality are complements. Proposition 3 shows these arguments to be valid if there are no income effects on the demand for \( x \) in any state, i.e., if utility is quasi-linear. It is also shown that in this no-income-effects case, the firm and the consumer agree as to which regime is better.

Proposition 3. Suppose that for each \( s, u^*(x, y) = q_s v(x) + r_s y \), with \( v' > 0 \) and \( v'' < 0 \). Then, the consumer and the firm have the same \textit{ex ante} ranking of the uninformed and informed consumer equilibria. They prefer the uninformed consumer equilibrium if income and quality are complements \( (r_1 < \ldots < r_3) \), and they prefer the informed consumer equilibrium if income and quality are substitutes \( (r_1 > \ldots > r_3) \).

Proof. For this utility function, (8) and (10) become, respectively, \( p_U(x) = (E_{q_s} / E_{r_s})v'(x) \) and \( p_s(x) = (q_s / r_s)v'(x) \). The firm prefers the regime with the higher expected demand curve, \( p_U(x) \) or \( E_{p_s}(x) \). Thus, it prefers the uninformed to the informed consumer equilibrium if and only if \( E_{q_s} / E_{r_s} > E(q_s / r_s) \).

Substituting these expressions for \( p_U(x) \) and \( p_s(x) \) into \( Eu^*(X_U, Y - p_U(X_U)X_U) \) and \( Eu^*(X^I, Y - p_s(X^I)X^I) \) yields, respectively,
\[
Eu^*(X_U, Y_U) = (v(x_U) - x_U v'(x_U))E_{q_s} + YE_{r_s},
\]
\[
Eu^*(X^I, Y^I) = (v(x^I) - x^I v'(x^I))E_{q_s} + YE_{r_s}.
\]
Since \( v'' < 0 \) implies that \( v(x) - xv'(x) \) increases in \( x \), the consumer prefers the regime with the greatest \( x \). Thus, since marginal costs are nondecreasing, she prefers the uninformed to the informed consumer equilibrium if and only if the marginal revenue curve \( xEp_s(x)' = (E_{q_s} / E_{r_s})[v'(x) + xv''(x)] \) is above the expected marginal revenue curve \( xEp_s(x)' = E(q_s / r_s)[v'(x) + xv''(x)] \). Hence, the consumer agrees with the firm that the uninformed consumer equilibrium is best if and only if \( E_{q_s} / E_{r_s} > E(q_s / r_s) \).

Now, note that
\[
E_{q_s} / E_{r_s} = E\left( \frac{q_s}{r_s} \right) + \frac{\text{cov}(r_s, q_s / r_s)}{E_{r_s}}.
\]

The definition of increasing quality in (6) implies that \( q_s / r_s \) increases in \( s \). The covariance of \( r_s \) and \( q_s / r_s \) is therefore positive (negative) if \( r_s \) increases (decreases) in \( s \). Hence, \( E_{q_s} / E_{r_s} > (<) E(q_s / r_s) \), so that both parties prefer the uninformed consumer equilibrium (the informed consumer equilibrium), if \( r_s \) increases (decreases) in \( s \). Q.E.D.

Proposition 3 is striking: for the given class of utility functions, either regime can Pareto-dominate the other, depending upon whether the marginal utility of income is higher or lower in high-quality states. As an extreme example, consider a new drug that has been proved safe and that can perhaps cure an otherwise incurable fatal disease. The drug should obviously be used even though it is not certain to work. A low-quality state entails death.
and hence, arguably, a lower marginal utility of income. Proposition 3 then implies that no attempt should be made to acquire and to disseminate information about the efficacy of the drug. Of course, the proposition may not apply if its assumptions are violated; for example, the assumption that information about quality does not allow the consumer to make better use of the product is violated if she would use another, proved drug only if the drug in question was disclosed to be ineffective.

The following example shows that even if income and quality are substitutes in utility, the consumer can prefer to be uninformed if her utility function is not quasi-linear. The example is not pathological; it is merely the simplest of portfolio problems.

Example 1. The firm sells an asset that returns $q$ dollars per unit in state $s$. The consumer cares only about income and is risk averse. Thus, $u'(x, y) = u(q, x + y)$, and $u$ is strictly concave. Note that $u'_s(x, y) = u'(q, x + y)$ decreases in $s$ because $q_1 < \ldots < q_s$, so that income and quality are substitutes. Nevertheless, contrary to the conclusion of Proposition 3, the consumer prefers the uninformed to the informed consumer equilibrium. This is so since her demand in each state when she is informed is perfectly elastic at $p_s = q_s$. The prices are therefore given by $p_s = q_s$, and the consumer receives only the utility $u(Y)$ of her endowment in every state. Her expected utility is greater than $u(Y)$ when she is uninformed, since then her inverse demand function $p_t(x)$ slopes down. The firm has the opposite preference: the informed consumer equilibrium is preferred to the uninformed consumer equilibrium. (In fact, the informed consumer equilibrium is easily shown to be fully efficient.)

The consumer in Example 1 prefers to be uninformed even though in the informed consumer regime she would be perfectly insured against the risk of low quality. The terms of trade are simply very bad for her when she is informed. In the next example the consumer prefers to be informed, but the firm prefers her to be uninformed. Taken together, Proposition 3 and Examples 1 and 2 show that all four patterns of agreement and disagreement about which regime is better can occur between the firm and the consumer.

Example 2. Let $u'(x, y) = q_s \ln (x) + (1 - q_s) \ln (y)$, where $0 < q_1 < \ldots < q_s < 1$. Then calculation yields $p_t(x) = (E_{q_s})Y/x$ and $p_s(x) = q_sY/x$. The firm therefore faces the same expected demand curve in both regimes, so that it is indifferent between the uninformed and the informed consumer equilibrium, and sets $x^U = x^I$. The consumer prefers the informed consumer equilibrium. To see this, note that $x^U = x^I$ implies

\[
E u'(x^U, y^U) - E u'(x^I, y^I) = E(1 - q_s) \ln (Y - p^U x^U) - E(1 - q_s) \ln (Y - p^I x^I) = (1 - E_{q_s}) \ln (Y - (E_{q_s})Y) - E(1 - q_s) \ln (Y - q_s Y) < 0,
\]

where the inequality follows from Jensen's inequality applied to the convex function $f(q) = (1 - q) \ln (Y - q Y)$.

The example can be altered so that the firm strictly prefers the uninformed consumer equilibrium. Let $u'(x, y) = \theta q_s \ln (x) + (1 - q_s) \ln (y)$, where $\theta > 1$. By continuity, the consumer prefers the informed consumer equilibrium if $\theta \approx 1$. But the firm prefers the uninformed consumer equilibrium: since $f(q) = q/[1 + (\theta - 1)q]$ is concave for $\theta > 1$,

\[
p_t(x) = \left( \frac{E_{q_s}}{1 + (\theta - 1)E_{q_s}} \right) \left( \frac{\theta Y}{x} \right) \]

\[
> E \left( \frac{q_s}{1 + (\theta - 1)q_s} \right) \left( \frac{\theta Y}{x} \right) = E_{q_s}(x).
\]

4. Conclusion

We conclude by noting the positive and normative consequences, in our model, of a law which requires firms to test and to disclose product quality.
Because firms will voluntarily test and disclose if they cannot credibly claim they are ignorant, a law designed to induce firms to test and to disclose will be redundant in this case. Hence, a necessary condition for the law to have an effect is that claims of ignorance be credible. We have shown that disclosure rules forcing firms to disclose all that they know will serve to make claims of ignorance credible, as will sufficiently high testing costs and, we believe, sufficient uncertainty on the part of consumers about the nature of testing.

Even if factors exist to make claims of ignorance credible, firms will still voluntarily test and disclose if they prefer, net of testing costs, to have informed rather than uninformed customers. A second necessary condition for the law to have an effect is, therefore, that firms prefer their customers to be uninformed. But if the demand functions of informed consumers exhibit negligible income effects, i.e., if their utility functions are quasi-linear, they will agree with firms about whether they should be informed. Thus, a necessary condition for a mandatory testing and disclosure law to be both effective and desired by consumers is that demand should depend significantly on income, which is the only case in which consumers could prefer to be informed when the firm prefers them to be uninformed.

Any policy conclusions based on these arguments should be taken strictly within the context of the model. In particular, it must be remembered that we have assumed information about quality to have no productive use, such as allowing the firm to make better production decisions or consumers to make better use of the product. While we believe the model has relevance if testing reveals information about the worth of financial securities or the efficacy of a new drug, it is not so relevant if testing reveals information about the safety of a new drug.

Another caveat to keep in mind is that we have assumed a very simple information structure. If consumers are totally unaware of what the possible product defects are, such as with a complicated and rarely purchased item like a child's toy, then an analysis that assumes consumers are proper Bayesians who can attach subjective probabilities to all possible events may be inappropriate. There may be better justification for mandatory testing and disclosure laws in this case.

Finally, we should mention two interesting questions that we have not addressed but that are on our future research agenda. First, by assuming quality is exogenous, we have not addressed the question of whether mandatory testing and disclosure laws can induce firms to provide higher quality. Second, we have not addressed the voluntary testing issue when there are several firms producing products with the same, or at least correlated, qualities; Milgrom and Roberts (1984) study part of this problem, the voluntary disclosure part, under the assumption that the sellers are exogenously informed.

Appendix

We fit the models together in this Appendix. Assume that in the model of Section 3, the firm controls how much the consumer knows by its testing and reporting choice. The firm's strategy choice is thus a triple \((x, \alpha, \beta)\), where \(x\) is an output level and \((\alpha, \beta)\) is a testing and reporting strategy, as in Section 2. The consumer's beliefs conditional on an announcement \(A \subseteq Q\) by the firm will be given by an inference function \(\gamma(s|A)\). If her beliefs after the announcement are \(\gamma\), the resulting inverse demand curve is given implicitly by

\[
p(x, \gamma) = \sum_{s \in Q} \frac{\gamma, \mu(x, Y - p(x, \gamma)x)}{\sum_{x \in Q} \gamma, \mu(x, Y - p(x, \gamma)x)}.
\]

(A1)

A monopoly equilibrium is a four-tuple \((\alpha^M, \beta^M, \gamma^M, x^M)\) such that \((\alpha^M, \beta^M)\) satisfies the feasibility condition (2) \((2')\) if disclosure rules are effective; \(\gamma^M\) satisfies the feasibility condition (3) and the rationality condition (4) \((4')\) if disclosure rules are effective; and the firm maximizes expected profit:

\[
(x^M, \alpha^M, \beta^M) \in \text{argmax} \alpha \sum_{s \in Q} \sum_{A \subseteq Q} \phi_{s}(A)\pi(x, \gamma^M(A))x + (1 - \alpha)p(x, \gamma^M(Q))x - c(x).
\]

(A2)

If we let \(\pi^M(\gamma) = p(x^M, \gamma)x^M - c(x^M)\), then (A2) implies

\[
(\alpha^M, \beta^M) \in \text{argmax} \alpha \sum_{s \in Q} \sum_{A \subseteq Q} \phi_{s}(A)\pi^M(\gamma^M(A)) + (1 - \alpha)\pi^M(\gamma^M(Q)).
\]

(A3)
Note that (A3) is of the same form as (5) or (5'). We conclude that the reduced form of the model in Section 3 is exactly as defined in Section 2.

Propositions 1 and 2 regarding voluntary disclosure and testing will hold if $\pi^M(\gamma)$ is monotonic in $\gamma$ in the sense of (1). This follows immediately if the price function $p(x, \gamma)$ is monotonic in the same sense, i.e., if

$$
p(x, e_\gamma) = \begin{cases} 
p(x, \gamma) & \text{if } \sum_{i \in s} \gamma_i = 0 \text{ for any } x > 0 \text{ and } e_\gamma \neq \gamma, \\
> p(x, \gamma) & \text{if } \sum_{i \in s} \gamma_i = 0, \end{cases}$$

(A4)

Note that (A4) implies the assertion made in Section 3 that $p_s(x) < p_{s+1}(x)$. Proposition A1 shows that (A4) follows from (6), which assumed that $u'_{i}/u'_{j} < u^{s+1}_{i}/u^{s+1}_{j}$.

Proposition A1. The inverse demand function $p(x, \gamma)$ satisfies (A4).

Proof: Let $s \in Q$ and $\gamma \neq e_\gamma$ satisfy $\gamma_{s+1} = \ldots = \gamma_{s} = 0$. We show that $p(x, e_\gamma) > p(x, \gamma)$ for all $x > 0$. The proof of the other part of (A4) is essentially the same.

Let $x(p, \tilde{\gamma})$ be the consumer's demand for $x$ when its price is $p$ and her beliefs are $\tilde{\gamma}$. Let $p > 0$ be a price such that $x(p, e_\gamma) > 0$. Lastly, let $h(x, \tilde{\gamma}) = \sum_{s \in Q} \tilde{\gamma}_s u_s(x, Y - px)$, and $\tilde{x} = x(p, e_\gamma)$. Then

$$0 = h(\tilde{x}, e_\gamma) = u'_{i}(\tilde{x}, Y - p\tilde{x}) - pu'_{i}(\tilde{x}, Y - p\tilde{x}),$$

since $\tilde{x}$ is positive and maximizes $h(x, e_\gamma)$. Hence,

$$h(\tilde{x}, \gamma) = \sum_{s \in s} \gamma_s [u'_{i}(\tilde{x}, Y - p\tilde{x}) - pu'_{i}(\tilde{x}, Y - p\tilde{x})]$$

$$= \sum_{s \leq s} \gamma_s [u'_{i}(\tilde{x}, Y - p\tilde{x}) - u'_{i}(\tilde{x}, Y - p\tilde{x})] u'_{i}(\tilde{x}, Y - p\tilde{x})$$

$$< 0,$$

since $u'_{i}/u'_{j} < u'_{i}/u'_{j}$ for all $t < s$. Because $h$ is quasi-concave in $x$, this shows that $x(p, \gamma) < \tilde{x} = x(p, e_\gamma)$. Thus, the demand curve $x(\cdot, e_\gamma)$ is to the right of the demand curve $x(\cdot, \gamma)$ at every $p$ for which $x(p, e_\gamma) > 0$. Because $p(\cdot, e_\gamma)$ and $p(\cdot, \gamma)$ are the corresponding inverse demand functions, this implies that $p(x, e_\gamma) > p(x, \gamma)$ for all $x > 0$. Q.E.D.

References


