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What the Seller Won't Tell You: Persuasion and Disclosure in Markets

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Imagine that you are considering an investment in a new public offering of a firm's shares. The firm's officers have visited your city to make a presentation that included an audited financial statement, an earnings forecast reviewed by its prestigious investment bankers, and an impressive demonstration of its new technology. Should such a presentation convince you to invest? How concerned should you be if no mention was made about a rumored competitor with a different technology? An economist reflecting on these same questions might wonder: Does the firm's need to convince naturally skeptical investors provide sufficient incentives for it to disclose accurate information in the right form and amount? Could regulations mandating disclosure improve the quality of investment decisions? What kinds of regulations are likely to be most helpful, and when?

It is not only in the financial investment sphere that buyers rely on sellers to supply information. For example, suppose that you are buying a new furnace to replace an old one that is not working well. The salesman displays a chart showing that the projected total life-cycle cost of one particular model, including capital costs and fuel usage over the projected lifetime of the furnace, is lower than for competing models you have considered. Should you worry about what the salesman is not telling you? Might fuel usage costs be less important for an especially well-insulated home like yours? What other issues didn't the salesman mention that could be relevant to your decision? If you talk to several sellers before buying, can you count on competition among them to bring out all the information you need to make a good decision? How does competition compare to regulation as a mechanism for encouraging sellers to provide valuable information to buyers?

Modern economics textbooks emphasize that the problem of adverse selection

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can alter the operation of markets in fundamental ways; for example, in a market where sellers cannot persuasively communicate to potential buyers information about the quality of a good, low-quality goods will predominate in the market, because sellers are not compensated for offering better-quality goods. However, relatively little attention has yet been paid to how sellers might supply information to mitigate or eliminate adverse selection problems, although sellers of good quality products clearly have a powerful incentive to do so. In modern economies, sellers routinely supply helpful information about their products, sometimes including test results and technical reports by government or independent laboratories. Seller reputations play a role in encouraging honest reporting. In addition, private-sector institutions including accounting firms, investment bankers, testing laboratories, consumer and hobbyist magazines, and others whose revenue-streams depend on their reputations may provide additional information or evaluate the accuracy of sellers' claims. Public-sector institutions also have a role: liability rules and laws against fraud help to ensure that reported information is accurate.

How effectively do these institutions mitigate adverse selection? How well does a system of private reporting work? When should we expect all the relevant information to be reported? If testing and reporting are costly, will too little testing and reporting be done? Or too much? When some information is withheld, what sort of information is withheld? How do rational buyers respond to such withholding? How are prices and welfare affected? What role is there for laws and regulations to improve the functioning of markets? We address these questions by studying the theory of *persuasion games*—games in which one or more sellers provide verifiable information to buyers to influence the actions they take.[1] Information can be "verifiable" either because buyers can directly check its accuracy or because there are institutions in place that effectively deter false claims by sellers. Throughout the analysis we assume that buyers are rational in the sense of making the best possible use of their sometimes limited information.

Two themes recur throughout the analyses. First, sophisticated buyers are consistently skeptical. When evidence is missing, they view that lack of evidence suspiciously, considering that any missing evidence is likely to be unfavorable to the seller, and they reduce their purchases accordingly.[2] The magnitude of this effect depends on what buyers believe about the seller's ability to obtain and communicate the missing information. Second, the combination of consumer skepticism and the seller's ability to reveal information provides a selective but still powerful incentive for sellers of all but the worst products to acquire and report information.

[1] The term "persuasion games" was coined by me and my coauthor (Milgrom and Roberts, 1986). These games, with their verifiable information, are distinguished from another important class of games—the *cheap talk* games of Crawford and Sobel (1982) and Farrell and Rabin (1996)—in which all reported information is unverifiable.

[2] Grossman (1981) and I (Milgrom, 1981) offer early general statements of this idea. A still earlier particular application of the idea to securities markets and takeover bidding was developed by Grossman and Hart (1980). My coauthor and I provide the most general statement of the result in Milgrom and Roberts (1986).

While empirical evidence about the extent of revealing information across an industry is meager, one study by Frankel, McNichols, and Wilson (1995) shows that more frequent issuers of securities also make more frequent earnings forecasts, which is consistent with the idea that frequent sellers have an extra incentive to supply information.

Indeed, in many cases, the key problem that arises is not that sellers are unwilling to reveal information, but that sellers can report and reveal information selectively. Some of the most striking examples of such behavior, and its potentially damaging consequences, are drawn from the pharmaceutical industry. In one case, Merck's arthritis drug, Vioxx, was reportedly found to double the risk of heart attacks for its users, but although this dangerous side effect was *suspected* by scientists for years before the drug was banned, there were no full studies confirming that danger and no reports alerting users to the risks. The Vioxx case, particularly the fact that the risks became apparent only after the drug had received approval from the Food and Drug Administration, has motivated recent policy proposals to change testing and reporting requirements for approved drugs (Harris, 2007). The Vioxx case is hardly unique. In another recent case, Eli Lilly allegedly instructed its salespeople to downplay the risks associated with its schizophrenia drug, Zyprexa, although some evidence suggested that risks might be severe (Berenson, 2006).

One policy response to prevent the selective release of information by sellers would be for the government to mandate disclosure of all of a seller's test results, whether positive or negative. But pinning down what a seller knows can be difficult. In many cases, the seller may have no verifiable test results to report, but may nevertheless be aware of indications of trouble. The seller then decides whether to run certain tests. In the easiest version of the theory, when the seller knows in advance what the outcome of any verifiable test will be, then there is an equilibrium in which sellers test and reveal "good news" and withhold "bad news" by not testing (Milgrom, 1981; see also, Dye, 1985; Verrecchia, 1983). When detailed information is missing and buyers are sophisticated enough to recognize that it is missing, the buyers must weigh competing explanations: perhaps the seller is intentionally withholding bad news, or perhaps the seller is uninformed, or perhaps testing and reporting are too costly to be worthwhile. With these confounding effects, sophisticated buyers will react to missing information by reducing their purchases—but not to the extent they would if they were to learn actual bad news about the product. In such a setting, the seller can benefit by refraining from conducting and reporting verifiable tests.

These ideas have widespread applications. Returning to our opening example about the public offerings of a firm's shares, suppose that the firm has disgruntled employees who could file an employment discrimination lawsuit. It will not benefit the firm that wishes to sell its stock to track down the details of that threat, because any news it turns up would most likely discourage investors and reduce its share price. In a legal and institutional framework which only demands that firms reveal what they already know, market forces do not solve the adverse selection problem.

Alternative legal rules may help. For example, the problem just described would be mitigated by a rule that holds the firm accountable for any unreported information if it *should have known* that information. "Should have known" might be operationally defined to mean that the firm could have run that test at a reasonable cost, or in other words, a well-informed firm would have run the test but for its private information that led it to believe that the test result would be unfavorable. In practice, the "should have known" standard might be replaced by an obligation for management to investigate certain categories of threats, where the ratio of threat cost to evaluation cost is especially high. The exact optimal rule depends on what is provable after the fact about what the firm knew or had reason to suspect.

Private-sector institutions can sometimes address the same sort of issue without the need for regulations. For example, an investment banker may be responsible for doing a thorough investigation of threats to the share value in anticipation of a public offering. However, a court that is examining what the seller should have known has an immense advantage over the investment banker in deciding what to check, because the court only needs to focus on whether the seller should have known about a negative event that actually occurred. The investment banker, in contrast, must evaluate the situation in advance, trying to understand what relatively inexpensive tests are available to deal with a number of threats that may or may not materialize. In this comparison, evaluating what should have been known after the fact can be cheaper and more effective.

An interesting and rarely emphasized benefit of competition is that competition can be helpful to buyers who are so poorly informed about a product that they do not even know which product attributes they should care about and what questions to ask. If there is no competition in the market, such a poorly informed buyer is at the mercy of an unscrupulous seller, but the situation is different when there are competing providers of information (Milgrom and Roberts, 1986). The situation is well illustrated by the buyer of a new furnace who knows only that the old furnace uses too much fuel and does not warm the house adequately. The buyer may be unaware that furnaces vary in how well they work with complementary products that are already installed in the house, such as an existing system of hot air ducts or an existing chimney or cooling system. Even an ignorant buyer can elicit the relevant information by promoting information competition among sellers, thus motivating each to explain why its furnace will work better than competitors' furnaces in the buyer's home. While information competition of this sort can be important, it has distinct limits. Self-interested furnace sellers would all omit telling the buyer about possible solutions that might not involve buying a furnace at all, like adding insulation below the roof. For information competition to work well, the buyer needs to know the set of relevant suppliers so that each relevant alternative has an advocate.

The remainder of this paper reviews in more detail the theoretical arguments about how sellers disclose information in an attempt to encourage buyers, and the potential role for regulation in encouraging efficient disclosure of information.

Skepticism and Unraveling

The situations we have described, in which a seller presents information in an attempt to persuade a buyer, can be represented using a class of games called persuasion games. The simplest persuasion game has two players: an informed seller and a risk-neutral uninformed buyer. The seller has private information about the quality of its product which we represent by a real variable θ, which takes on a finite number of possible values: 1, . . . *N*. Higher values of θ represent better quality. The seller's only move in the game is to make a report about θ to the otherwise uninformed buyer, who then makes a purchase decision. If there were no legal or other institutions that would penalize a seller for false statements and no incentives provided through repeat purchasing, then the seller's report would be nothing but cheap talk and could hardly influence the buyer. Thus, we assume a legal/institutional structure that prevents the seller from making a manifestly false report. In the basic model, we assume that the seller's report will be truthful—but it will not necessarily be complete or detailed. Although the theory allows the seller's report about quality to take a quite general form, we can illustrate the theory by limiting attention to reports of the form: "the quality of my product is at least *x*."

The buyer's decision, which depends on the seller's report, is some scalar *q*. For this paper, we will think of *q* as being either the quantity that the buyer purchases or the highest price that the buyer would agree to pay to acquire a unit. Two assumptions guide the analysis. The first assumption is innocuous: the seller prefers the buyer to choose a higher *q*—that is, either to buy a higher quantity or to stand ready to pay a higher price. The second assumption is that the marginal value of an increase in *q* to the buyer is increasing in quality θ of the seller's good. In particular this means that if the quality level is higher, then the optimal choice of *q* will be higher—that is, the buyer will be willing to buy a higher quantity or pay a higher price.

This second assumption, while intuitively plausible, is not entirely general. For example, if higher-quality light bulbs are expected to last longer, then a purchaser might buy fewer bulbs. As a consequence, the makers of long-lasting light bulbs might be disinclined to mention to the consumer that there is no need to buy replacement bulbs, so the theory described here does not apply to such sellers. Despite potential exceptions like this one, there are plentiful instances in the real economy in which a seller wants buyers to believe that the quality of its product is high.

Let us consider the case where, even after the seller's report, the buyer remains uncertain about the quality. Here, a second implication of the marginal value assumption arises: if the consumer thinks that the quality of the good lies in the interval between *i* and a higher level *j*, then the assumptions imply the corresponding optimal decision lies between q_i and q_j.

So far, our assumptions have focused mainly on describing the buyer's preferences. The last ingredient in our model is an assumption about the kinds of

reports available to the seller. In our simplest model, we assume that whatever else a seller can do, when the actual quality is θ, the seller can produce a certification report that proves the actual quality is at least θ. This assumption would be satisfied, for example, if the seller could always prove the precise quality of its product or if it can prove a tight lower bound on the quality of its product.[3]

This combination of assumptions justifies a thorough-going skepticism on the part of the buyer. If the seller chooses not to prove that the quality exceeds some threshold when the buyer knows that it could do so, then the buyer *can* react by being extremely cautious in deciding what to purchase, buying only the quantity corresponding to the minimum proven quality. We will show below that this is indeed the *only* outcome that can happen in (perfect Bayesian) equilibrium.

The equilibrium of a persuasion game consists of two kinds of objects: *strategies* describing what each player would do in every circumstance the player might encounter and a *belief function* describing what the buyer would believe after every possible report by the seller. Let S^* denote the seller's equilibrium strategy so that $S^*(\theta)$ denotes what the seller reports when the true quality is θ. Let π^*_S be a probability distribution over possible qualities denoting what the buyer would believe in equilibrium after hearing the report S. Finally, let q^*_S denote the equilibrium decision by the buyer when the seller reports S. We write $q^*_S = q^*(\pi^*_S)$ to emphasize that the buyer's decision depends on S only to the extent that the report affects the buyer's beliefs about quality, π^*_S. To be an equilibrium, the triple consisting of the seller report S^*, the buyer decision q^*, and the buyer's belief about quality π^* must satisfy three conditions:

1) The seller always makes the report S that maximizes its net profits, subject to the constraint that the report S is truthful. (In the simplest persuasion games, the relevant net profit is $q^*(S)$.)

2) After observing the report S, the buyer chooses q to maximize its expected payoff, given its beliefs π^*_S.

3) The buyer's beliefs π^*_S after any report of the quality level S must be consistent with S, because the seller is constrained to be truthful, and must be determined by Bayes' rule whenever that applies.

The persuasion game with these three equilibrium conditions leads to:

Proposition 1: *Buyers are maximally skeptical and make efficient choices.* In every equilibrium:

1) The buyer is *maximally skeptical*. For any quality report S by the seller, the buyer believes that the actual quality of the good is equal to the minimum quality, denoted by $m(S)$, consistent with the seller's report.

2) The buyer's decision q after observing any report of quality level S is

[3] Glazer and Rubinstein (2006) characterize equilibrium in a persuasion game where the buyer's decision is binary and the marginal values assumption is dropped. There is, as yet, no extension of that model that endogenizes prices or evaluates disclosure policies, so we omit that model from this review.

determined by that skepticism: thus, the choice $q_S^* = q_{m(S)}$. Given the report S, the buyer purchases the quantity or sets the reserve price corresponding to the smallest proven quality.

3) When the actual quality of the good is i, several reports by the seller are consistent with equilibrium, but all lead to the same outcome. The seller's equilibrium report might specify that its quality is exactly i or that the product quality is in some class for which the minimum possible quality is i. Whatever equilibrium report the seller makes, the maximally skeptical buyer draws the same inference and makes the same choice.

Notice that the outcome of this simple persuasion game is an efficient one that seems to leave no role for government intervention: a buyer purchases just as if fully informed. In this simple scenario, there would be no distortions and no use for regulations to govern the transaction and the release of information.

The argument used to prove how the equilibrium in Proposition 1 arises is commonly called the *unraveling argument*. The usual presentation first shows that the highest quality sellers always make reports of quality that distinguish their products from all others, and then the remaining sellers face a similar game. The next highest quality sellers therefore report quality levels to distinguish themselves from lower-quality types, and the process repeats itself. For this argument to work, it must be common knowledge that a seller *can* distinguish its product from lower-quality products and sellers must *benefit* by doing so. Both conditions are ensured by our assumptions as specified above.

When Uncertainty Mutes Skepticism

When we introduce uncertainty about whether the seller is able to supply verifiable information to distinguish itself from lower-quality sellers, the analysis changes. The buyer still casts a skeptical eye on missing information, but the skepticism is muted because the buyer is unsure about what information the seller *could* have reported. In terms of the buyer's beliefs about quality, news that a product is very bad is strictly worse than no news and leads the buyer to purchase a smaller quantity or to set a lower reserve price. Consequently, in equilibrium, the seller always withholds very bad news and reports only relatively good news.

To capture these ideas, we adapt a model of Shin (2003), assuming that the quality of the good is multidimensional and represented by N characteristics.[4] For each characteristic j, the good has some score x_j and the quality of the good is just the sum of these: $\theta = x_1 + \cdots + x_n$. The buyer's value for acquiring a quantity q is proportional to that overall quality measure; it is $\theta v(q)$.

[4] The models introduced by Shin (1994, 2003) provide interesting treatments of how selective reporting of information of the sort considered here affect security price dynamics. Essentially, good information is readily reported while bad information dribbles out, which can (with additional assumptions) lead to predictions about asymmetric security returns and other interesting dynamics.

The seller may or may not have a verifiable test report of the score x_j on any particular characteristic j. However, the seller always knows the various scores and which characteristics are verifiable. The buyer has no direct access to any of this information. In particular, the buyer does not know whether the seller is able to provide a verifiable test result concerning any characteristic. Test reports and their availability are statistically independent, so no report carries information about any other characteristics.

Equilibrium in this setting is described in:

Proposition 2: Uncertainty about the seller's information mutes skepticism and damages welfare.

In the persuasion game with uncertain verification, there is a unique equilibrium, which is described by a triple consisting of the seller's report S^*, the buyer's decision q^*, and the buyer's belief about quality π^*. (The report S^* of the seller to the buyer is now a *list* indicating test results for some characteristics and no results for others.) In this equilibrium:

1) The seller reports the outcome of a test j only when a verifiable test is available and the test result is "sufficiently good."

2) Given any report S by the seller about the characteristics of the good, the buyer will form a probability distribution π about the quality of that good that treats each characteristic as statistically independent. If the seller reports an outcome for test j, then the buyer places a probability of 1 on the reported value. However, if the seller makes no report about test j, then the buyer allows both that the seller may not know the value and that the seller may be concealing the value because it is low. In this case, the buyer will apply Bayes theorem in a way consistent with the seller's strategy to weight the two possibilities and bases its belief about the test report on that calculation.[5]

3) The buyer's choice of q maximizes the payoff for the buyer, given these beliefs: $q^*(S) = q(\pi_S)$.

Unlike the previous model, this model leaves a potential role for liability rules or direct regulation, because firms do sometimes withhold information in equilib-

[5] To illustrate the calculation, suppose that for each j, x_j is uniformly distributed on [0,1] and the probability that test report j is verifiable is γ. Let $\bar{x} = (\sqrt{1-\gamma} - (1-\gamma))/\gamma$. If the seller reports that the test for quality j is α, the buyer can apply Bayes theorem to deduce that

$$\pi_s^*(\{x_j \leq \alpha\}) = \begin{cases} \alpha/(\bar{x} + (1-\bar{x})(1-\gamma)) & \text{for } \alpha \leq \bar{x} \\ (\bar{x} + (\alpha - \bar{x})(1-\gamma))/(\bar{x} + (1-\bar{x})(1-\gamma)) & \text{for } \alpha > \bar{x}. \end{cases}$$

The numerator is the joint probability that the true test value is less than α and no report is made. In the denominator is the probability of the event that no report is made, either because the test result is below $\bar{x}$ or because it is above $\bar{x}$ but not verifiable. For values of α below $\bar{x}$, the joint probability in the numerator is simply the probability that the test value is less than α, because such results always remain unreported regardless of whether they are verifiable. For higher values of α, the joint probability is the probability that the test value is too low to lead to a report *plus* the probability that the test value is between $\bar{x}$ and α and that no verifiable report is possible.

rium. Suppose a court or regulator could determine after the fact that a seller withheld negative information and could impose liability for losses incurred by the buyer. Then, the seller's anticipation of an additional cost of withholding information would cause it to reveal more information to the buyer at equilibrium, leading to better buyer decisions and greater total welfare.

While the model of this section lends some useful insights, it is still too thin to enable usable welfare analyses. It assumes verifiable information about quality characteristics to be either available or not available, but omits the seller's decision about whether to acquire verifiable information about quality. Examples in the introduction like those about continued testing for FDA-approved drugs highlight the importance of that decision. To focus attention on the seller's incentives to conduct verifiable tests and how those incentives affect overall welfare, it is helpful to make some additional assumptions.

Pecuniary Externalities of Disclosure

We next consider an extended persuasion game in which, in addition to making a report S, the seller also sets the price p of its product. In response, the buyer makes a yes-or-no decision to buy a fixed number of units of the product; in terms of an earlier example, a person either buys a new furnace or does not buy one. Let $v^*(\theta)$ denote the consumer's full-information reservation price—the highest price that the buyer would pay for a unit of the good of a certain quality level. In equilibrium, the seller can work out how its report S will affect that reservation price, so it sets the product price to that level in order to collect all that the buyer is willing to pay.

Suppose now that the seller incurs a cost to make a verifiable test of attribute j. It turns out that the seller's incentive to test and reveal information is at least sometimes excessive. Indeed, when testing is costly, a seller often has an even greater incentive to verify product quality than it would under any efficient arrangement, as Jovanovic (1982) demonstrates. To understand the source of this extra incentive, let us focus on the seller's decision at the margin about whether to conduct n or $n + 1$ tests. Suppose the buyer expects the seller to run n tests and the seller knows that. (The argument we are about to make does not depend on whether this is an equilibrium belief, just that the buyer cannot observe the actual number of tests run.) If the seller conducts the $n + 1^{st}$ test and its result is positive, the seller can report that favorable result and charge a higher price. The buyer, facing verifiable evidence of the product's high quality, will be willing to pay that price. If the result is negative, the seller can withhold that information. Since the buyer only expected n tests and has no reason to suspect that the actual number was $n + 1$, the seller can charge just the same price in that case as if it had not performed the extra test. Thus, by running an unexpected additional test and reporting its result selectively, the seller can raise its price on average, causing a transfer from the buyer to the seller. That pecuniary externality encourages the

seller to engage in excessive testing. In equilibrium, the sophisticated buyer understands the seller's testing incentives and makes the correct assessments on average. Still, because the seller benefits at the buyer's expense by engaging in extra testing, there is too much testing in the market compared to the efficient level.

Indeed, it is even possible that a regulator who could ban costly seller testing altogether might sometimes increase efficiency by doing so. Here is an extreme example to illustrate the possibility. Suppose there is just one relevant product attribute and that the seller incurs no cost in supplying the product, so the efficient outcome is that a purchase should always occur. If the seller does not test, then the buyer forms an opinion about quality accordingly, and purchases the product. That outcome is efficient and avoids testing costs. If the seller does test and can show a higher level of quality, then the buyer will pay more when purchasing the product. In this setting, the costly testing affects only the price, not the production of the product or whether the sale occurs. Because testing is costly and adds no value, a value-maximizing regulator would ban it.

Despite the fact that testing is costly to the seller and cannot increase its average revenues, in equilibrium the seller cannot generally refrain from testing. When testing is sufficiently cheap and buyers will pay more for a product of verified quality, the seller can increase its net profit by testing, reporting selectively, and thus raising its average price.

Although this example is extreme, its qualitative conclusions can be extended usefully. The most interesting extension is characterized by two conditions. First, to distinguish from the extreme case just analyzed, we assume that production is costly enough that an uninformed buyer would *not* want to buy, even if the good were priced at cost. That makes information about quality potentially productive, since it can change the buyer's decision when the product quality is actually high. Second, to eliminate additional extreme cases, we assume that testing costs are low enough that some testing is socially efficient, yet high enough that conducting and revealing every possible test is not optimal. In such a situation, an omniscient social planner would no longer proscribe all costly testing. Instead, the planner would want to reveal product information only when 1) trade actually adds positive value and 2) the net value added, which is the buyer's reservation value $v(\theta)$ minus the supply cost, exceeds the cost of the testing required to convince the buyer to make the purchase. In other words, even when the product is very good, a total-surplus-maximizing planner would want the seller to use only the least costly verifiable test sufficient to cause the purchase to proceed.

Comparing the seller's interests with those of a social planner leads to two important observations. First, since the price-setting seller captures the whole surplus from any transaction (the buyer just breaks even), the seller prefers testing over no-testing whenever the planner does. But the seller may want to test even more often: when the product is actually bad and there are no net gains from trade, there may still be enough favorable information from selective reporting to convince the buyer to make a purchase. So the seller prefers to test at any time the planner would test, and at other times too.

Second, for every level of quality, the seller will always want to spend at least as much on testing as the planner, and sometimes more. This is obvious for the case where the planner would prefer to do no testing. But also when the planner prefers some testing, it would like to do that in the least costly way that causes the transaction to proceed. The seller's interests are different. Besides wanting the transaction to proceed, the seller wants also to get the highest possible price net of its costs, which generally calls for revealing different information than the planner would prefer. In many of our simple models, "different" translates into "more," because reporting unexpectedly good news can only raise the price of the product.

Both of these observations amount to saying that verifiable testing combined with selective reporting creates a pervasive negative pecuniary externality in equilibrium. Holding the buyer's beliefs fixed, suppose the seller runs an additional test and reports its results selectively. Compare that to the situation where no additional test is conducted. If the test result is good, that allows the seller to charge a higher price; if it is bad, the seller withholds the report and gets the same price as if no test had been run. Hence, with selective reporting, extra testing leads to higher average prices. Selective reporting thus leads to a negative pecuniary externality which encourages excessive testing.

In equilibrium, buyers form their beliefs correctly knowing that sellers will engage in these practices, so the seller's manipulations do not lead to systematically higher prices. Instead, the equilibrium is a sort of rat race similar to that found by Akerlof (1976), in which the seller's effort to extract rents raises costs unnecessarily and causes a loss of value that the seller itself must bear.

Our findings for this model are summarized in:

Proposition 3: Sellers spend too much on discretionary quality testing. In the equilibrium of the persuasion-and-pricing game described here:

1) Prices are set so that the buyer's expected payoff, conditional on the buyer's information, is always zero: that is, the price paid by the buyer is the reservation value based on the quality signal S from the seller.

2) For each level of quality, the seller spends as much or more on testing and verification as the amount that would be spent by a total-surplus-maximizing planner.

3) Overspending on testing occurs whenever the product quality is sufficiently high and the cost of additional testing is sufficiently low.

To illustrate the equilibrium, we consider a special case. Again, assume that the buyer's reservation value $v(\theta)$ is the sum of the values of the characteristics of the good, each of which is uniformly distributed on [0,1]. Suppose that testing a characteristic costs c, where $0 < c < \frac{1}{2}$. If a characteristic is verifiably reported, the buyer treats that as the actual measure of quality. A buyer who sees no report about a specific characteristic infers, based on the uniform distribution, that the expected value of the unreported characteristic is c. In equilibrium, the seller verifies a quality characteristic when it is greater than $2c$. Thus, the buyer is right to infer that the average quality of unverified characteristics is c and the seller is right to infer

that it is worth the cost of verifying only when the actual value of the characteristic exceeds 2c. This affirms the intuition that, in equilibrium, the seller reports characteristic j whenever its quality is sufficiently large or the cost of testing is sufficiently low.

The models underlying Propositions 2 and 3 assume that the seller is fully informed about its own product. In that situation, if the product characteristics could be costlessly verified after consumption, then costly pre-sale verification would be unnecessary, because a liability rule that holds the seller responsible after-the-fact for any false statements would deter dissembling. That sort of after-the-sale verification effectively returns us to the equilibrium described in Proposition 1, in which buyer skepticism leads to full disclosure and there is no need for regulation.

There are two reasons why, in practice, after-the-sale verification of claims is unlikely to provide sufficient protection for buyers. The first reason involves asymmetric information. For example, a pharmaceutical company may be aware that patients using its new drug are experiencing poorer results than had been expected, but the company may not yet have run tests or evaluated the clinical data to determine the nature or extent of the problem. Similarly, a firm issuing new shares may be aware of complaints about its employment or environmental policies, but it may not yet have evaluated what legal risks those policies create. In these situations, the seller arguably has no verifiable information that is governed by simple mandatory disclosure rules and it may fear that generating such information can only lead to negative results. Some valuable testing and disclosure opportunities would then be suppressed.

A second reason why after-the-sale verification of claims may be insufficient to restore efficiency is that the buyer may not know what to ask or how to interpret the available information. A seller of ceiling insulation may fail to report that the product contains a dangerous chemical, such as asbestos, and even a buyer who has a sophisticated understanding of the strategic situation may lack the product-specific knowledge or scientific understanding to know what information to expect, what questions to ask, or what to make of a report that a product does contain a certain chemical.

When Revelation Should be Compelled

Regulatory remedies for the two problems just described may need to be more intrusive or difficult to administer than merely mandating reporting of known test results. The two problems are also different and may require different solutions.

For the first, let us focus on the pharmaceutical industry examples in which one problem is to induce the seller to use its *unverifiable* private information to make proper decisions about which tests to perform. Regulation that tries to force testing before the product is offered for sale falters on an information problem: if the regulator knew which of the missing tests to compel, then a sophisticated buyer

could equally well be skeptical about the absence of those tests. Such regulation could be effective only at the cost of creating a bureau that informs itself in ways the buyer cannot. An alternative to compelling testing is to impose liability rules, but the relevant rules are different from the ones discussed above, because the problem here is neither one of false reporting nor one of withholding verifiable information. What is needed in this setting is to hold the seller liable for failures to reveal promptly not only the verifiable information that the seller knew, but also the information that it *should have* known under the circumstances. Such a regulation works better than attempts to compel immediate disclosure if accumulating evidence about a product defect comes to light only gradually and if discovery in a legal proceeding can reveal when the seller had become aware of a *possible* problem. In practice, such a system can work only if it is eventually possible to establish *what* the seller should have known and *when* it should have known it.

The second problem, in which consumers don't know enough about the relevant product even to ask the most relevant questions, has different potential remedies. The simplest solution, in principle, is for an industry regulator who is an expert in the subject matter to mandate the relevant material disclosures. Such regulations are sometimes attempted. For example, there have long been regulations requiring companies that sell whole life insurance policies to forecast the policy's cash value accumulations and net realized costs at various future dates, although these forecasts rely on many assumptions which are not guaranteed. Competition among sellers is sometimes a partial substitute for regulation in this kind of setting, because it can compel sellers to reveal sufficient information to enable buyers to make good decisions. These kinds of required testing will also be complemented by various kinds of after-the-sale regulation, like laws against fraud, and implied warranties of merchantability or product fitness, all of which can sometimes mitigate problems in reporting and adverse selection issues more generally.

Game theory, with its standard assumptions of rationality, does not yet have a generally accepted way to accommodate models of buyers who are so unaware of relevant facts that they cannot even reason about them. The buyer who has never even heard of asbestos—let's call that buyer a "novice"—is different from an uninformed buyer who is uncertain about how dangerous asbestos may be but is able to ask about it. Even a novice buyer can still be *sophisticated*—fully aware both of being a novice and of the kinds of strategies that sellers use to mislead novice buyers. For such buyers, an equilibrium analysis still applies.

To study markets with such sophisticated novice buyers, consider a product with several different characteristics and a seller who reports the quality on just one of these characteristics. A novice buyer who cannot recognize the name of any characteristics even after the seller reports one will be unable to determine whether the characteristic the seller reports about is the relevant one.[6] In a persuasion game with a novice buyer, there is an equilibrium in which sellers always report the test

[6] For a formal model of novice buyers, see Milgrom and Roberts (1986).

result about the characteristic on which the product scores best. If there is always some characteristic on which any product gets a perfect score, then the seller's report is wholly uninformative. Even a novice buyer can recognize that and choose q accordingly. This finding can be formally proven as:

Proposition 4: In the described circumstances, sophisticated novice buyers will ignore seller-provided information.

However, if the buyer is not quite a complete novice and is able to name some characteristics, then the seller can convey some potentially useful information. According to this procedure, the buyer asks the seller for information about a characteristic that the buyer can name. There is some probability that this characteristic is relevant for overall quality, and so the seller's verifiable report (or the seller's refusal to make any report) will reveal that. If the seller responds with a good report, the buyer's decision can also account probabilistically for the limited amount of information that such a report on a single characteristic conveys.

The persuasion game with a novice buyer (or an "unaware" buyer) creates the possibility that an expert regulator could, by requiring product labeling for relevant characteristics, encourage more useful and informative disclosures. Labeling emerges as a remedy in our analysis when consumers are novices—that is, so unfamiliar with the product that they don't know what to ask about—and when all consumers have the same concerns. With too much consumer heterogeneity, however, the labeling solution fails, because the regulator does not know which characteristic needs to be reported. Mandating full reporting does not solve the problem if the novice buyer is assumed to have limited ability to learn the names and relevance of various product characteristics.

Another remedy that could, in principle, lead to an efficient outcome arises when there are some agreed product standards, the seller is required to disclose product defects, and there is after-the-sale liability for failures to disclose. Consumer heterogeneity, however, is again a problem, particularly if the buyer's characteristics can change over time. In such cases, it may be difficult to verify whether the seller has reported the right information for the particular buyer. Reporting too much information in this situation leads to information overload, in which the buyer may fail to notice the most relevant information. One example is an initial public offering in which the investor receives a long prospectus listing so many possible risks—including competition, obsolescence, lawsuits, toxic waste, and so on—that the most important risks fall out of focus. A second example is health information on food products, for which the usual list of vitamins, minerals, sugars, calories from fats, and the list of other facts is so long that consumers may give up trying to interpret the disclosure.

Regulation or Competition?

Our example of the furnace purchase illustrates the possibility that buyers may differ in their relevant characteristics. For example, in choosing a furnace, it may

be important to take into account the size of the home, the capacity of hot air ducts, the amount of insulation, the construction of the chimney, and other factors. An uninformed buyer will probably know only a few of the characteristics and not necessarily the ones that are most relevant. Should a regulator select just one or a few characteristics about which to require reporting; if so, how should the regulator choose? Will competition between sellers create an incentive to report the relevant characteristics?

Competition between sellers of a product will not always suffice, because the sellers of a product are unlikely to offer information that leads to purchase of a completely different product. For example, without regulation, it may be that no furnace seller will report to the buyer that the best choice is to repair the old furnace or install better insulation, or no tobacco company will report that tobacco products can cause lung disease and other ailments. However, if we set the more limited objective of having the buyer make the best choice from among the sellers' offerings and if each seller offers only a single product, then sellers with the best offerings will be motivated to point out the characteristics that most distinguish their own products. Competition can lead to useful disclosures even to novice buyers, provided that they are sophisticated, because sellers will seek to highlight the relative advantages of their products for the particular buyer.

To study this sort of competition, we revisit the novice buyer scenario of the preceding section. Suppose there are two sellers, both of which are perfectly informed about the relevant product characteristic and about how each product scores on that characteristic. Each seller names a characteristic, which we interpret as the claim that this characteristic is the relevant one. The novice buyer then identifies a characteristic that one of the sellers has named and requests that both sellers report about that characteristic. Each seller may then make a verifiable report either about the identified characteristic or about the one it had named. Finally, the sellers quote prices for their products and the buyer chooses one of the products or neither. For simplicity, assume that the sellers' supply cost for the product is zero. Proposition 5 describes an equilibrium of the game in which the buyer treats the two sellers symmetrically.[7]

Proposition 5: *Sophisticated novice buyers benefit strongly from competing sellers*:

1) If a seller has a better test report for the relevant characteristic than the other seller, then it names the relevant characteristic to the buyer at the first round of the game. Otherwise, the seller names any characteristic on which it gets a perfect test report.

2) The novice buyer randomizes and selects one of the two named characteristics, each with equal probability. The sellers each report their test result on the buyer-selected characteristic.

3) The buyer beliefs are formed as follows: If a seller reports the test result for

[7] The other equilibria have the buyer favoring one seller or another, asking about that seller's reported characteristic with a probability greater than ½.

the buyer-identified characteristic, then the buyer believes that report is equal to the test result. If a seller fails to name the required characteristic, then the buyer infers that its test result for the buyer-identified characteristic is zero.

4) The buyer's beliefs determine values for the two products.

5) Given these values, the sellers engage in price competition, with the winning seller's price set just low enough to attract the buyer and make price reductions unprofitable for the other seller.

In this equilibrium, the novice buyer may do remarkably well in extracting some information from competition among the sellers. The seller with the better-quality product names the relevant characteristic to win the sale, even if it would withhold that information in the absence of competition. Compared to the regulatory solution, if the relevant characteristic varies among buyers in a way that sellers understand, then competition leads to more relevant and valuable reporting than could result from any uniform regulatory solution. Thus, in the furnace example, a seller might explain to a particular buyer that, given the local climate, house size and layout, and installed insulation, a competitor's higher-efficiency furnace is not worth the extra cost, despite standard calculations which show that such a furnace would reduce total costs for an "average" house. In this kind of situation, if the buyer can understand the seller's calculation, then competition can be an effective partial solution to the problem of revealing product quality. However, so long as the buyer has a limited capacity to process relevant information, some mistaken decisions are still unavoidable.

Conclusion

When buyers are sophisticated, markets provide powerful incentives for sellers to supply useful and verifiable product information. Such incentives can sometimes go a long way toward alleviating problems of adverse selection. Yet sellers may still have an incentive to test selectively, based on their unverifiable suspicions about which tests will make their products look good. Regulation, especially in the form of creating liability for withholding material information, can help to mitigate the costs of nondisclosure. More empirical evidence about the role of laws and regulations mandating disclosure is needed to supplement the general empirical observation that some disclosure regulations do benefit stock markets (La Porta, Lopez-de-Silanes, and Shleifer, 2006).

The regulatory problem becomes harder when buyers are *novices*—that is, when they do not even recognize the names of relevant product characteristics and when complete information about the product is too complex and detailed for the buyer to analyze. If buyers are not too heterogeneous, then expert regulators can in some cases mandate disclosure of the most significant product characteristics. That remedy becomes problematic, however, when heterogeneity among buyers multiplies the number of potentially significant product characteristics. Competi-

tion among sellers helps somewhat, because sellers who understand the buyer's needs will be led to emphasize the important characteristics on which their own products have an advantage. However, if the best decision for a buyer lies outside the set offered by the sellers, then no seller will have an incentive to reveal this fact.

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References

Akerlof, George. 1976. "The Economics of Caste and of the Rat Race and Other Woeful Tales." *Quarterly Journal of Economics*, 90(4): 599–617.

Berenson, Alex. 2006. "Eli Lilly Said to Play Down Risk of Top Pill." *New York Times*, December 17. At http://www.nytimes.com/2006/12/17/business/17drug.html.

Crawford, Vincent P., and Joel Sobel. 1982. "Strategic Information Transmission." *Econometrica*, 50(6): 1431–51.

Dye, Ronald. 1985. "Disclosure of Nonproprietary Information." *Journal of Accounting Research*, 23(1): 123–45.

Farrell, Joseph, and Matthew Rabin. 1996. "Cheap Talk." *Journal of Economic Perspectives*, 10(3): 103–18.

Frankel, Richard, Maureen McNichols, and G. Peter Wilson. 1995. "Discretionary Disclosure and External Financing." *Accounting Review*, 70(1): 135–50.

Glazer, Jacob, and Ariel Rubinstein. 2006. "A Study in the Pragmatics of Persuasion: A Game Theoretical Approach." *Theoretical Economics*, 1(4): 395–410.

Grossman, Sanford. 1981. "The Informational Role of Warranties and Private Disclosure about Product Quality." *Journal of Law and Economics*, 24(3): 461–83.

Grossman, Sanford, and Oliver Hart. 1980. "Disclosure Laws and Takeover Bids." *Journal of Finance*, 35(2): 323–34.

Harris, Gardiner. 2007. "FDA Widens Safety Reviews on New Drugs." *New York Times*, January 31. http://www.nytimes.com/2007/01/31/washington/31fda.html.

Jovanovic, Boyan. 1982. "Truthful Disclosure of Information." *Bell Journal of Economics*, 13(1): 36–44.

La Porta, Rafael, Florencio Lopez-de-Silanes, and Andrei Shleifer. 2006. "What Works in Securities Laws?" *Journal of Finance*, 41(1): 1–32.

Milgrom, Paul. 1981. "Good News and Bad News: Representation Theorems and Applications." *Bell Journal of Economics*, 12(2): 380–91.

Milgrom, Paul, and John Roberts. 1986. "Relying on the Information of Interested Parties." *Rand Journal of Economics*, 17(1): 18–32.

Shin, Hyun Song. 1994. "News Management and the Value of Firms." *Rand Journal of Economics*, 25(1): 58–71.

Shin, Hyun Song. 2003. "Disclosures and Asset Returns." *Econometrica*, 71(1): 105–33.

Verrecchia, Robert. 1983. "Discretionary Disclosure." *Journal of Accounting and Economics*, vol. 5, pp. 179–94.