Disclosure Rules in Contract Law

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Abstract

How does the prospect of sale affect the seller's incentive to investigate – to acquire socially valuable information about the asset? How do the disclosure rules of contract law influence the investigation decision? Shavell (1994) showed that, if sellers and buyers are symmetrically informed, at the pre-investigation stage, then a mandatory disclosure rule leads to a first-best outcome, and a voluntary disclosure rule leads to a suboptimal outcome. But in many real-world cases owners of assets have better information about their assets, even before they investigate. In such asymmetric information settings, we show, mandatory disclosure no longer attains a first-best outcome. And, under certain conditions, voluntary disclosure is the more efficient rule. In particular, investigation is socially valuable, because it facilitates efficient investment. We distinguish between investment opportunities that arise when investigation reveals that the asset is of low-value ("remediation investments") and investment opportunities that arise when investigation reveals that the asset is of high-value ("improvement investments"). With remediation investments, mandatory disclosure is always more efficient than voluntary disclosure. But with imporovement investments, voluntary disclosure can be the more efficient rule. We further enrich the analysis by introducing a third rule: the mandatory post-disclosure rule, which requires disclosure of material information, but only after the contract is concluded. We show that this rule can be more efficient than both voluntary disclosure and mandatory (pre-contract) disclosure.

1. Introduction

1.1 Motivation

Consider the following example:

Example: Underground Water. Having lived in the house for the past ten years, Owner suspects that there is underground water beneath the house, which might damage its foundations. (Namely, Owner knows that the probability that underground water exists beneath her house is larger than the average probability of underground water in the relevant area.) Owner could hire a surveyor and find out whether underground water in fact exists.

    (a) *Remediation.* If underground water is indeed found, Owner could invest in remediation – to fix any water damage and to avoid further damage.

    (b) *Improvement.* If underground water is not found, Owner could improve the property. Specifically, Owner can construct an office building on the property. An office building can only be constructed on property with solid foundations – foundations that are not threatened by underground water.

In the future, Owner may want to sell the house to Buyer. If and when Buyer becomes the owner of the house, Buyer can also make remediation or improvement investments.[1]

In such an example, it may be efficient for Owner to hire the surveyor. The information that the surveyor would provide – about the existence of underground water – is productive information (Hirshleifer, 1971; Cooter and Ulen, 2011). It can be used to enhance the value of the property. Specifically, we distinguish between two types of

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[1] The example is based on cases that considered the duty of a seller (or subdivider) of real estate to disclose to a purchaser that the property has a history of underground water. See, e.g., Barnhouse v. City of Pinole, 133 Cal. App. 3d 171, 189 (1982); Buist v. C. Dudley De Velbiss Corp., 182 Cal. App. 2d 325 (1960). *See generally* Janet Fairchild, *Fraud Predicated on Vendor's Misrepresentation or Concealment of Danger or Possibility of Flooding or other Unfavorable Water Conditions*, 90 A.L.R.3d 568 (Originally published in 1979).

value-enhancing investments – remediation investments and improvement investments. Remediation investments refer to investment opportunities that arise for low-value assets – in our example, when underground water is found. Improvement investments refer to investment opportunities that arise for high-value assets – in our example, when there is no underground water.[2]

Investigation can produce socially valuable information – information that can result in value-enhancing investments. And the value of the information may well exceed the cost of acquiring it, i.e., the cost of hiring the surveyor. But will Owner acquire the information? (The information is "deliberately acquired" information a'la Kronman 1978.) Will she disclose the information to Buyer? (Assuming that the disclosure itself is costless and credible, e.g., delivery of the surveyor's report, as in Grossman 1981 and Milgrom 1981.)

The answers to these questions depend on the legal regime. In the United States, courts impose a duty to disclose material information prior to a sale, but the scope of this duty is subject to ongoing debate.[3] It is, therefore, important to study the efficiency properties of different disclosure rules. Should we adopt a mandatory disclosure (MD) rule, where Owner must disclose the surveyor's report (if such a report is obtained), or should we rather prefer a voluntary disclosure (VD) rule, where Owner can choose whether or not to disclose the surveyor's report (if such a report is obtained)?

In an important paper, Shavell (1994) compares the efficiency of MD and VD under the assumption that, prior to any investigation, Owner and her potential Buyer are symmetrically informed: they both know the average likelihood that underground water exists beneath the house. But, in many cases, information is asymmetric. Owners of assets often know more, about their assets, than potential buyers. In our example, even before hiring the surveyor Owner's prior about the likelihood that underground water

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[2] Compare: Shavell (1994) assumes that the value of investment increases with value of the asset.

[3] See RESTATEMENT (SECOND) CONTRACTS § 161 cmt d. (1981) ("A seller of real or personal property is, for example, ordinarily expected to disclose a known latent defect of quality or title that is of such a character as would probably prevent the buyer from buying at the contract price"). See also Obde v. Schlemeyer 353 P. 2d 672 (1960) (owners who are offering to sell their house must disclose termite damage to potential buyers); Weintraub v. Krobatsch, 317 A.2d 68 (N.J. 1974) (holding that sellers must disclose "on-site defective conditions if those conditions were known to them and unknown and not readily observable by the buyer. Such conditions, for example, would include radon contamination and a polluted water supply"); Cooter and Ulen (2011), at pp. 360-361; Posner (2003), at p. 111.

threatens the foundations was higher than the statistical average. We introduce information asymmetry into the Shavell model and show how it alters standard results about the acquisition and disclosure of information.[4]

1.2 Mandatory Disclosure vs. Voluntary Disclosure

Shavell shows that, with symmetric information, a mandatory disclosure regime provides Owner with optimal incentives to acquire information – to hire the surveyor. Namely, if Owner must disclose the surveyor's findings to Buyer, Owner will hire a surveyor when it is efficient to do so. Asymmetric information qualifies this result. A duty to disclose no longer provides optimal incentives for owners to collect information. Specifically, owners with a more negative prior (type L owners), who think that the likelihood of underground water is above average, will investigate too little – they will not hire a surveyor when it is efficient to do so. In contrast, owners with a more positive prior (type H owners), who think that the likelihood of underground water is below average, will investigate too much – they will hire a surveyor even when it is inefficient to do so. Type L owners are reluctant to (potentially) reveal the low-value of their assets. They are less likely to investigate as they seek to pool with those type H owners who face high investigation costs and thus fail to investigate. Type H owners, on the other hand, investigate too much in order to avoid such pooling.

In Shavell's model, a mandatory disclosure (MD) rule provides first-best incentives. It is clearly better than the alternative rule, the voluntary disclosure (VD) rule, which induces excessive investigation (and only selective disclosure of information – when the surveyor reports good news). With asymmetric information, the analysis is more subtle. Type H owners investigate too much under MD, and even more under VD. Therefore, MD is always better than VD for type H owners. For type L owners, we get inadequately low investigation levels with MD and excessively high investigation levels with VD (in the Remediation case, VD induces more investigation than MD, but this higher level can

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[4] We assume that Owner cannot credibly convey her private information. One could imagine that such private information could be conveyed through the use of warranties, e.g., "I'll pay you $X (or you can rescind the contract), if you ever find underground water." We also assume that the fact of investigation itself (i.e., whether the seller chose to investigate) is not observable by the buyer.

still be below the socially optimal investigation level). Therefore, for type L owners VD can be more efficient than MD. And when VD's advantage, for type L owners, is sufficiently large, VD can be the most efficient rule overall.

Interestingly, VD can be the most efficient rule only in the Improvement case. In this case, the extra investigation induced by VD has social value, since owners who receive good news disclose it to buyers who then make improvement investments. In the Remediation case, MD always dominates VD. Here, the extra investigation induced by VD has no social value. Value-enhancing investments arise only when owners get bad news, but in a voluntary disclosure regime owners will not disclosure bad news to buyers.

1.3 Mandatory Post-Contract Disclosure

In addition to the two standard rules (MD and VD), we introduce a third rule – the mandatory post-contractual disclosure (MPCD) rule. This new rule requires disclosure of material information, but only after the contract is concluded.[5] MPCD is a hybrid rule, providing incentives to investigate that are stronger than those provided by MD but weaker than those provided by VD. MPCD has an important advantage vis-a-vis VD: good information will be voluntarily disclosed pre-contract, as with the voluntary disclosure rule; but now bad information will also be disclosed, albeit post-contract. The buyer won't be able to rescind the contract, but at least he will be able to utilize the information and invest in remediation – to mitigate the harm from underground water. In other words, MPCD induces more efficient remediation investments. For this reason MPCD is more efficient than VD. MPCD can also be more efficient than MD. Recall that MD leads to inadequate investigation by type L owners. MPCD can bring the

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[5] The MPCD rule would need to come with several "technical" supplements. In particular, we would need a rule that denies enforcement to a contractual clause that purports to rescind the contract if Owner discloses bad news post-contract. Also, there is a concern that a buyer who received bad news post-contract would turn around and sell the property to another buyer. We could address this concern by reverting back to MD after the first sale (or if buyer resells within a specified period of time).

With MPCD, owners who investigate and learn good news would voluntarily disclose pre-contract and owners who investigate and learn bad news would remain silent pre-contract and then disclosure post-contract. A variant on our MPCD rule would prohibit any pre-contract disclosure. This variant, however, would be difficult to implement. In particular, it would be difficult to prevent an owner with a good surveyor's report from showing this report to a potential buyer.

investigation level closer to the first best. Therefore, MPCD can outperform the two traditional rules.

1.4 Reality Checks

Asymmetric information and warranties. We replace the symmetric information assumption in Shavell (1994) with an asymmetric information assumption. We believe that in many cases owners have better information than potential buyers, even before any investigation. Our analysis applies where the owner's informational advantage is based on a non-observable (and non-verifiable) signal. Otherwise, an unraveling dynamic could restore informational symmetry.

Warranties are a well-know solution to the asymmetric information problem (Grossman 1981). An owner who knows that the probability of underground water in her property is below average could promise the buyer: "I'll pay you $X (or you can rescind the contract), if you ever find underground water." And, again, an unraveling dynamic could restore informational symmetry. In reality, however, the buyer's concern would not be limited to underground water, and the warranty would need to be more general: "I'll pay you $X (or you can rescind the contract), if you ever find *anything wrong* with the asset." But such a broad warranty, and even a narrower warranty focused on underground water, might interfere with the efficient allocation of risk between the parties. Therefore, it seems unlikely that warranties will completely eliminate the asymmetric information problem. Indeed, the case law is replete with examples where, for one reason or another, the contract did not include a warranty. (See also Section 6 below.)

Buyer's questions and the viability of VD. In a VD regime, what happens if the buyer asks a silent owner: "Did you investigate and get bad news?" If the law forces the owner to respond truthfully, then such a question transforms VD into MD. The viability of VD, therefore, requires a legal permission to lie in response to this question. If the law (through a VD rule) allows you to keep certain information private, then it cannot allow another person to extract that information by asking a simple question. This general observation applies to any analysis of VD rules, not only to the analysis in this paper (see Porat and Yadlin 2016).

Probability of sale. In our model, the asset is sold with certainty closely after the owner decides whether to investigate (and, if the owner decides to investigate, closely after the owner investigates). In our motivating example, and in many real-world cases, the owner, when deciding whether to investigate, anticipates only a probability of a sale sometime in the (perhaps distant) future. This discrepancy between the model and the real-world does not detract from the analysis. The model is designed to study possible distortions caused by the prospect of sale. The distortions that we identify would simply need to be discounted by the probability (and temporal) distance of a possible sale.[6] More importantly, such discounting would apply equally to the different legal rules (MD, VD and also MPCD) and thus would not affect the comparison between them.

Investigation by Buyer. We focus on the owner's incentives to investigate, and how these incentives are affected by the legal regime. In many real-world cases, the buyer can also investigate (before deciding to purchase the asset). The implications of possible investigation by the buyer are briefly discussed in Section 6 below. It is important to emphasize that investigation by the buyer, when it occurs, is generally a poor substitute for disclosure by the seller (Lefcoe, 2004).

1.5 Literature

The literature on acquisition of information prior to disclosure begins with Farrell and Sobel (1983). Shavell (1994) builds on Farrell and Sobel (1983), adding the possibility that information has a social value. Another early contribution is Matthews and Postlewaite (1985) who focus on quality testing in product markets. They assume costless investigation (or "testing") and do not consider the possibility of remediation or other value-enhancing investments. More recently, Polinsky and Shavell (2012) study firms' incentives to acquire information about product risks. All of these models assume that pre-investigation the seller and buyer are symmetrically informed.

A related literature studies incentives to disclose information, under the assumption that initially, and without investigation, the seller is informed; and the buyer is not.

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[6] For example, if Owner expects to continue living in the house for another 10 years before selling, she will have a strong incentive to investigate and the prospect of a future sale, and the applicable disclosure rule, will have a smaller effect on the investigation decision.

Daughety and Reinganum (2013, Section 3.B.2) provide an excellent survey of the literature on disclosure of product safety information, in the products liability context. See also: Bolton and Dewatripont (2005, chapter 5), surveying literature on the disclosure of information.

Our paper seeks to combine these two strands in the literature. Like the first strand, we focus on the incentives to acquire information. And, like the second strand, we assume that initially, pre-investigation, the parties are asymmetrically informed.

The paper proceeds as follows: Section 2 lays out our framework of analysis. Section 3 derives and compares outcomes and welfare levels for the two standard rules (MD and VD). The basic model assumes that value-enhancing investments are possible only if Owner decided to investigate (and this investigation revealed the true nature of the asset). Section 4 studies an extension, where investment is possible, even without prior investigation. Section 5 introduces the new, MPCD rule and compares it to the two standard rules. Section 6 offers concluding remarks, briefly discussing alternative legal rules, investigation by the buyer, and applications to other contractual settings (beyond the asset sale case).

2. Framework of Analysis

2.1 Setup

There are two parties, Seller and Buyer. The timeline of the game is as follows:

T=0: Seller owns an asset. The asset has two possible values $v \in \{v_L, v_H\}$, where $v_H > v_L$ and $Pr(v_L) = Pr(v_H) = \frac{1}{2}$. Let $\bar{v} \equiv \frac{1}{2}v_L + \frac{1}{2}v_H$ denote the average value of the asset. Both Seller and Buyer know the distribution of values.

T=1: Seller receives a non-verifiable signal that reveals, to Seller only, whether the asset is more likely to be a low-value asset or a high-value asset. Specifically, Seller

receives a non-verifiable signal $\sigma \in \{L, H\}$, with $Pr(\sigma = L) = \frac{1}{2}$ and $Pr(\sigma = H) = \frac{1}{2}$. A type L seller, who received $\sigma = L$, knows that $Pr(v_L) = \alpha$ and $Pr(v_H) = 1 - \alpha$, and that the expected value of the asset is: $\bar{v}_L = \alpha v_L + (1 - \alpha)v_H$. A type H seller, who received $\sigma = H$, knows that $Pr(v_L) = 1 - \alpha$ and $Pr(v_H) = \alpha$, and that the expected value of the asset is: $\bar{v}_H \equiv (1 - \alpha)v_L + \alpha v_H$. We assume, without loss of generality, that $\alpha \geq \frac{1}{2}$.[7] The seller's type is private information. (Note that the model in Shavell (1994) is a special case of our model, captured by $\alpha = \frac{1}{2}$.)[8]

T=2: Seller decides whether to investigate. If Seller investigates, then Seller learns for sure whether the asset is a low-value asset or a high-value asset. Specifically, Seller can choose to investigate, namely, to invest k and obtain a verifiable signal $s \in \{L, H\}$. The cost, k, is distributed across sellers according to $F(k)$.[9] (The distribution function applies to all sellers, regardless of the actual value of the asset and regardless of the non-verifiable signal that they received.[10]) An investigation reveals the true value of the asset with certainty. If the actual value of the asset is $v = v_L$, then a seller who invests k will obtain a verifiable signal $s = L$. If the actual value of the asset is $v = v_H$, then a seller who invests k will obtain a verifiable signal $s = H$. Formally, $Pr(v_L|s = L) = 1$ (and, correspondingly $Pr(v_H|s = L) = 0$) and $Pr(v_H|s = H) = 1$ (and, correspondingly, $Pr(v_L|s = H) = 0$).[11] Seller's

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[7] A more general model would let $Pr(v_L) = \beta$ and $Pr(v_H) = 1 - \beta$ for a type H seller, with $\beta < \alpha$. The results would be qualitatively similar.

[8] Two alternative ways of conceptualizing this framework are: (1) The parties start off with a common prior: $Pr(v_L) = Pr(v_H) = \frac{1}{2}$, and then the seller receives a non-verifiable signal σ and updates her beliefs. (2) The parties start off with different priors – the buyer with $Pr(v_L) = Pr(v_H) = \frac{1}{2}$; and the seller with either $Pr(v_L) = \alpha$ and $Pr(v_H) = 1 - \alpha$, or $Pr(v_L) = 1 - \alpha$ and $Pr(v_H) = \alpha$.

[9] In some cases, the heterogeneity in investigation costs can be relatively small, e.g., when all sellers have access to the same market for surveyors and these surveyors charge a relatively uniform price. In other cases, the heterogeneity in investigation costs can be larger, e.g., when the market for surveyors is less competitive, leading to greater price dispersion, and different sellers, with different search costs, are more or less able to find a surveyor who charges a low price.

[10] An alternative assumption would allow for two different distribution functions – one for sellers who received $\sigma = L$ and one for sellers who received $\sigma = H$. This alternative assumption would be more realistic, if knowing the high probability that your asset is compromised, e.g., by underground water, also provides information that facilitates further investigation of the problem.

[11] Shavell (1994) assumes that either only seller can investigate or only buyer can investigate. We adopt the assumption that only seller can investigate.

investigation cost, k, is private information. Buyer knows only the distribution of investigation costs, $F(k)$. Moreover, Seller's decision whether to investigate is private information.

T=3: Buyer appears and the parties negotiate a sale of the asset from Seller to Buyer. (Seller has no outside option.[12]) Before the negotiations commence, there is a disclosure stage: With MD, a seller who investigated at T=1 discloses the investigation results - the verifiable signal s – to Buyer. With VD, a seller who investigated at T=1 decides whether to disclose the investigation results to Buyer. We assume that disclosure is truthful or verifiable (as in Grossman and Hart 1980, Grossman 1981, Milgrom 1981, and Shavel 1994). Namely, a disclosing seller can only disclose the actual results of the investigation; and a non-investigating seller cannot disclose anything and must remain silent. This assumption captures situations where the investigation produces verifiable results, such as a surveyor's report. After the disclosure stage, negotiations commence. Following Shavell (1994), we assume that Buyer pays what he believes to be the (expected) value of the asset. This assumption gives Seller all the bargaining power.

T=4: Buyer decides whether to invest in the asset. We assume that knowing the true value of the asset increases social welfare, by enabling value-enhancing investments (i.e., we assume "productive information"). These value-enhancing investments can take one of two forms:

(1) Remediation investments: These investment opportunities arise uniquely for low-value assets (see Example 1 above). Specifically, if $v = v_L$, Buyer can increase the value of the asset from v_L to $v_L + \Delta v$, at a cost of $x < \Delta v$. Let $\Delta \tilde{v} \equiv \Delta v - x$.

(2) Improvement investments: These investment opportunities arise uniquely for high-value assets (see Example 2 above). Specifically, if $v = v_H$, Buyer can

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[12] This assumption (which follows Shavell 1994) prevents an unraveling that may occur, if sellers who are offered a low price can simply exit the market.

increase the value of the asset from v_H to $v_H + \Delta v$, at a cost of $x < \Delta v$. Let $\Delta\tilde{v} \equiv \Delta v - x$.[13]

We study the implications of these two investment opportunities separately. (In some applications, both types of investment opportunities may be present. It would be straightforward to extrapolate from our analysis to such scenarios.) We initially assume that investment is possible only if Buyer knows for sure, as a result of disclosure by a seller who decided to investigate, whether the asset is a low-value asset or a high-value asset. This assumption seems plausible in many cases. For example, one would need to know the source, and precise location, of the underground water problem, before it can be remediated. In an extension (in Section 4), we allow for investment without precise knowledge of the asset's value.[14]

2.2 The First-Best

We derive the first-best outcome and welfare level, as a benchmark for the analysis of the alternative disclosure rules (in the following sections). Consider the Remediation case first. For a type L seller, the expected value of the asset, without investigation, is: $\bar{v}_L = \alpha v_L + (1 - \alpha)v_H$. The expected value, with investigation, is: $\alpha(v_L + \Delta\tilde{v}) + (1 - \alpha)v_H = \bar{v}_L + \alpha\Delta\tilde{v}$, and the social value of information is: $I^*(L) = \alpha\Delta\tilde{v}$. For a type H seller, the expected value of the asset, without investigation, is: $\bar{v}_H = (1 - \alpha)v_L + \alpha v_H$. The expected value, with investigation, is: $(1 - \alpha)(v_L + \Delta\tilde{v}) + \alpha v_H = \bar{v}_H + (1 - \alpha)\Delta\tilde{v}$, and the social value of information is: $I^*(H) = (1 - \alpha)\Delta\tilde{v}$. In the Remediation case, type L sellers are more likely to learn that they have an opportunity to make value-enhancing investments and thus $I^*(L) > I^*(H)$.

In the Improvement case: The expected values, without investigation, are as in the Remediation case: $\bar{v}_L$ for type L sellers and $\bar{v}_H$ for type H sellers. For type L sellers, the expected value, with investigation, is: $\alpha v_L + (1 - \alpha)(v_H + \Delta\tilde{v}) = \bar{v}_L + (1 - \alpha)\Delta\tilde{v}$, and

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[13] The assumption here is that remediation cannot transform a low-value asset into a high-value asset, or that such remediation is not cost effective. Otherwise, the focus returns to the remediation investment (since, given remediation, the other investments do not depend on the initial value of the asset).

[14] Much of the analysis applies if we flip the order, such that Seller decides whether to invest in the asset at T=3 and then Buyer appears in T=4.

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the social value of information is: $I^*(L) = (1 - \alpha)\Delta\tilde{v}$. For type H sellers, the expected value, with investigation, is: $(1 - \alpha)v_L + \alpha(v_H + \Delta\tilde{v}) = \bar{v}_H + \alpha\Delta\tilde{v}$, and the social value of information is: $I^*(H) = \alpha\Delta\tilde{v}$. In the Improvement case, type H sellers are more likely to learn that they have an opportunity to make value-enhancing investments and thus $I^*(H) > I^*(L)$.

In the first-best, type L sellers with $k < I^*(L)$ investigate and type L sellers with $k \geq I^*(L)$ do not investigate. Similarly, type H sellers with $k < I^*(H)$ investigate and type H sellers with $k \geq I^*(H)$ do not investigate. A seller who investigates discloses the information to the buyer. With remediation investments, the buyer invest x, if he learns that $v = v_L$. With improvement investments, the buyer invest x, if he learns that $v = v_H$. (Alternatively, the seller invests herself.)

In both the Remediation case and the Improvement case, the first-best social welfare level is:

$$W^*(\sigma) = \bar{v}_\sigma + \int_0^{I^*(\sigma)} (I^*(\sigma) - k) f(k)dk$$

where $\sigma \in \{L, H\}$.

2.3 The Investigation Decision

A central decision in our model is the seller's decision whether to investigate. The different disclosure regimes produce different incentives to investigate, and these differences play an important role in determining the relative efficiency of the alternative regimes. To determine whether the seller will choose to investigate, we compare the payoff of an investigating seller to the payoff of a seller who chooses not to investigate. Let $\pi_I(\sigma)$ denote the expected payoff of a seller who chooses to investigate and let $\pi_{NI}(\sigma)$ denote the expected payoff of a seller who chooses not to investigate, where $\sigma \in \{L, H\}$ represents the seller's type (i.e., a type L seller who received a signal $\sigma = L$ or a type H seller who received a signal $\sigma = H$). The value of information to the seller is thus given by $I(\sigma) = \pi_I(\sigma) - \pi_{NI}(\sigma)$. A seller with $k < I(\sigma)$ will investigate; a seller with $k \geq I(\sigma)$ will not.

Of course, $\pi_I(\sigma)$, $\pi_{NI}(\sigma)$ and $I(\sigma)$ depend on the disclosure rule (MD or VD), as detailed below. Yet, several general features are worth highlighting at this point. First, a non-investigating seller always remains silent. Let π_S denote the expected payoff of a silent seller and note that this payoff does not depend on the seller's type (since the buyer cannot distinguish between different types of silent sellers, they are all offered the same price). We thus have $\pi_{NI}(\sigma) = \pi_S$. This payoff, π_S, varies between the two rules – and so we have π_S^{MD} and π_S^{VD} – and these variations will prove critical to the analysis.

Next, consider the expected payoff of an investigating seller. With both rules, if the seller investigates and finds v_H, she will disclose this information, and buyer will pay v_H in the Remediation case or $v_H + \Delta\tilde{v}$ in the Improvement case. The difference between the two rules arises when the seller investigates and finds v_L. With MD, the seller will disclose this information, and the buyer will pay $v_L + \Delta\tilde{v}$ in the Remediation case or v_L in the Improvement case. Therefore, in the Remediation case, the expected profit of a type L seller who investigates is: $\pi_I^{MD}(L) = \bar{v}_L + \alpha\Delta\tilde{v}$, and the expected profit of a type H seller who investigates is: $\pi_I^{MD}(H) = \bar{v}_H + (1 - \alpha)\Delta\tilde{v}$. In the Improvement case, the expected profit of a type L seller who investigates is: $\pi_I^{MD}(L) = \bar{v}_L + (1 - \alpha)\Delta\tilde{v}$, and the expected profit of a type H seller who investigates is: $\pi_I^{MD}(H) = \bar{v}_H + \alpha\Delta\tilde{v}$.

With VD, a seller who investigates and finds v_L will remain silent and get π_S. (This is obviously true in the Improvement case, since $\pi_S^{VD} > v_L$. In the Remediation case, a seller who investigates and finds v_L will remain silent, if $\pi_S^{VD} > v_L + \Delta\tilde{v}$. We assume that this condition holds; otherwise, VD would be equivalent to MD.) Therefore, in the Remediation case, the expected profit of a type L seller who investigates is $\pi_I^{VD}(L) = (1 - \alpha)v_H + \alpha\pi_S^{VD}$, and the expected profit of a type H seller who investigates is $\pi_I^{VD}(H) = \alpha v_H + (1 - \alpha)\pi_S^{VD}$. In the Improvement case, the expected profit of a type L seller who investigates is $\pi_I^{VD}(L) = (1 - \alpha)(v_H + \Delta\tilde{v}) + \alpha\pi_S^{VD}$, and the expected profit of a type H seller who investigates is $\pi_I^{VD}(H) = \alpha(v_H + \Delta\tilde{v}) + (1 - \alpha)\pi_S^{VD}$.[15]

We can now calculate the value of information for each rule. With MD, in the Remediation case, we have: $I^{MD}(L) = \pi_I^{MD}(L) - \pi_{NI}^{MD}(L) = \bar{v}_L + \alpha\Delta\tilde{v} - \pi_S^{MD}$ for type L sellers, and $I^{MD}(H) = \pi_I^{MD}(H) - \pi_{NI}^{MD}(H) = \bar{v}_H + (1 - \alpha)\Delta\tilde{v} - \pi_S^{MD}$ for type H sellers.

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[15] The expected payoff of all sellers is always positive and, since sellers don't have an outside option, there is no concern that some group of sellers will exit the market.

And in the Improvement case, we have: $I^{MD}(L) = \pi_I^{MD}(L) - \pi_{NI}^{MD}(L) = \bar{v}_L + (1-\alpha)\Delta\tilde{v} - \pi_S^{MD}$ for type L sellers, and $I^{MD}(H) = \pi_I^{MD}(H) - \pi_{NI}^{MD}(H) = \bar{v}_H + \alpha\Delta\tilde{v} - \pi_S^{MD}$ for type H sellers.

With VD, in the Remediation case, we have: $I^{VD}(L) = \pi_I^{VD}(L) - \pi_{NI}^{VD}(L) = (1-\alpha)(v_H - \pi_S^{VD})$ for type L sellers, and $I^{VD}(H) = \pi_I^{VD}(H) - \pi_{NI}^{VD}(H) = \alpha(v_H - \pi_S^{VD})$ for type H sellers. And in the Improvement case, we have: $I^{VD}(L) = \pi_I^{VD}(L) - \pi_{NI}^{VD}(L) = (1-\alpha)(v_H + \Delta\tilde{v} - \pi_S^{VD})$ for type L sellers, and $I^{VD}(H) = \pi_I^{VD}(H) - \pi_{NI}^{VD}(H) = \alpha(v_H + \Delta\tilde{v} - \pi_S^{VD})$ for type H sellers.

For both rules, we have $I(H) > I(L)$: The benefit from investigation is greater for the type H seller, which means that type H sellers will investigate more often that type L sellers.

As noted above, the expected payoff of a silent seller, and how it varies between the two rules, plays a central role in the analysis. When facing a silent seller, the buyer infers the equilibrium "mix" of possible silent sellers. With MD, there are two possible groups of silent sellers:

(i)   Type L sellers who did not investigate. In equilibrium, there will be $\frac{1}{2}\left(1 - F\left(I^{MD}(L)\right)\right)$ such sellers. The expected value of their asset is $\bar{v}_L$.

(ii)   Type H sellers who did not investigate. In equilibrium, there will be $\frac{1}{2}\left(1 - F\left(I^{MD}(H)\right)\right)$ such sellers. The expected value of their asset is $\bar{v}_H$.

Aggregating across the two groups, the total number of silent sellers is: $S^{MD} = \frac{1}{2}\left[1 - F\left(I^{MD}(L)\right)\right] + \frac{1}{2}\left[\left(1 - F\left(I^{MD}(H)\right)\right)\right]$. Let $\theta_L^{MD} = \frac{1}{2}\left(1 - F\left(I^{MD}(L)\right)\right)/S^{MD}$ denote the share of non-investigating type L sellers among all silent sellers. Let $\theta_H^{MD} = \frac{1}{2}\left(1 - F\left(I^{MD}(H)\right)\right)/S^{MD}$ denote the share of non-investigating type H sellers among all silent sellers.

With VD, there are three possible groups of silent sellers:

(i)   Type L sellers who did not investigate. In equilibrium, there will be $\frac{1}{2}\left(1 - F\left(I^{VD}(L)\right)\right)$ such sellers. The expected value of their asset is $\bar{v}_L$.

(ii) Type H sellers who did not investigate. In equilibrium, there will be $\frac{1}{2}\left(1 - F\left(I^{VD}(H)\right)\right)$ such sellers. The expected value of their asset is $\bar{v}_H$.

(iii) Sellers, of both type L and type H, who investigated and found v_L. We group type L and type H sellers together here, since for both types the value of the asset is v_L. In equilibrium, there will be $\frac{1}{2}\alpha F\left(I^{VD}(L)\right) + \frac{1}{2}(1 - \alpha)F\left(I^{VD}(H)\right)$ such sellers.

Aggregating across the three groups, the total number of silent sellers is: $S^{VD} \equiv \frac{1}{2}\left[\left(1 - F\left(I^{VD}(L)\right)\right) + \alpha F\left(I^{VD}(L)\right)\right] + \frac{1}{2}\left[\left(1 - F\left(I^{VD}(H)\right)\right) + (1 - \alpha)F\left(I^{VD}(H)\right)\right]$. Let $\theta_L^{VD} = \frac{1}{2}\left(1 - F\left(I^{VD}(L)\right)\right)/S^{VD}$ denote the share of non-investigating type L sellers among all silent sellers. Let $\theta_H^{VD} = \frac{1}{2}\left(1 - F\left(I^{VD}(H)\right)\right)/S^{VD}$ denote the share of non-investigating type H sellers among all silent sellers. And let $1 - \theta_L^{VD} - \theta_H^{VD}$ denote the share of investigating sellers (who found v_L) among all silent sellers.

The expected payoff of a silent seller equals the expected value of the asset to the buyer, when offered by a silent seller. This expected value, in turn, depends on the equilibrium "mix" of silent sellers as characterized above. With MD, the expected payoff of a silent seller is $\pi_S^{MD} = \theta_L^{MD}\bar{v}_L + \theta_H^{MD}\bar{v}_H$. With VD, the expected payoff of a silent seller is $\pi_S^{VD} = \theta_L^{VD}\bar{v}_L + \theta_H^{VD}\bar{v}_H + (1 - \theta_L^{VD} - \theta_H^{VD})v_L$.

3. Outcomes and Welfare

We begin by separately analyzing each regime: mandatory disclosure in Section 3.1 and voluntary disclosure in Section 3.2. We then compare the two regimes in Section 3.3.

3.1 Mandatory Disclosure

We first consider the incentives to investigate. Recall that, in the Remediation case, we have: $I^{MD}(L) = \bar{v}_L + \alpha\Delta\tilde{v} - \pi_S^{MD}$ and $I^{MD}(H) = \bar{v}_H + (1 - \alpha)\Delta\tilde{v} - \pi_S^{MD}$. And in the Improvement case, we have: $I^{MD}(L) = \bar{v}_L + (1 - \alpha)\Delta\tilde{v} - \pi_S^{MD}$ and $I^{MD}(H) = \bar{v}_H +$

$\alpha\Delta\tilde{v} - \pi_S^{MD}$ for type H sellers. Also recall that the expected profit of a seller who does not investigate is: $\pi_S^{MD} = \theta_L^{MD}\bar{v}_L + \theta_H^{MD}\bar{v}_H$.

We compare the private value of information with mandatory disclosure to the social value of information. In the Remediation case: For type L sellers, we have: $I^{MD}(L) = \bar{v}_L + \alpha\Delta\tilde{v} - \pi_S^{MD} \leq \alpha\Delta\tilde{v} = I^*(L)$; and for type H sellers, we have: $I^{MD}(H) = \bar{v}_H + (1 - \alpha)\Delta\tilde{v} - \pi_S^{MD} \geq (1 - \alpha)\Delta\tilde{v} = I^*(H)$. In the Improvement case: For type L sellers, we have: $I^{MD}(L) = \bar{v}_L + (1 - \alpha)\Delta\tilde{v} - \pi_S^{MD} \leq (1 - \alpha)\Delta\tilde{v} = I^*(L)$; and for type H sellers, we have: $I^{MD}(H) = \bar{v}_H + \alpha\Delta\tilde{v} - \pi_S^{MD} \geq \alpha\Delta\tilde{v} = I^*(H)$.

These results are stated in the following lemma.

Lemma 1: In both the Remediation case and the Improvement case, (1) $I^{MD}(H) \geq I^*(H)$, and (2) $I^{MD}(L) \leq I^*(L)$.

Type L sellers do not investigate enough with MD. Conversely, type H sellers investigate too much with MD. Type L sellers, reluctant to (potentially) reveal the low-value of their assets, are less likely to investigate as they seek to pool with silent type H sellers. Type H sellers, on the other hand, investigate in order to avoid such pooling.

Multiple equilibria. The game defined by the MD rule can have multiple equilibria. For example, there can be a "high equilibrium," where parties believe that many type H sellers investigate, i.e., where $\hat{I}^{MD}(H)$ and $F\left(\hat{I}^{MD}(H)\right)$ are high. If many type H sellers investigate, then the share of type H sellers among non-investigating sellers is low,[16] and thus the expected profit of a non-investigating seller, π_S^{MD}, is low. And a low π_S^{MD} implies a high $I^{MD}(H)$ (recall that $I^{MD}(H) = \bar{v}_H + \alpha\Delta\tilde{v} - \pi_S^{MD}$), confirming parties' beliefs. There can also be a "low equilibrium," where parties believe that few type H sellers investigate, i.e., where $\hat{I}^{MD}(H)$ and $F\left(\hat{I}^{MD}(H)\right)$ are low. If few type H sellers

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[16] The analysis is more subtle: Recall that the difference, $I^{MD}(H) - I^{MD}(L)$, is constant, specifically, $I^{MD}(H) - I^{MD}(L) = \bar{v}_H - \bar{v}_L + (2\alpha - 1)\Delta\tilde{v}$. This means that when $I^{MD}(H)$ is higher, $I^{MD}(L)$ is also higher. Still, for certain distribution functions, $F(\cdot)$, a higher $I^{MD}(H)$, even when accompanied by a higher $I^{MD}(L)$, increases the share of type H sellers among investigating sellers and decreases the share of type H sellers among non-investigating sellers.

investigate, then the share of type H sellers among non-investigating sellers is high and thus the expected profit of a non-investigating seller, π_S^{MD}, is high. And a high π_S^{MD} implies a low $I^{MD}(H)$, confirming parties' beliefs.

In both the Remediation case and the Improvement case, the social welfare level is:

$$W^{MD}(\sigma) = \bar{v}_\sigma + \int_0^{I^{MD}(\sigma)} (I^*(\sigma) - k) f(k) dk$$

where $\sigma \in \{L, H\}$. The welfare function resembles the first-best welfare function, albeit with a different investigation threshold.

Based on Lemma 1, we can compare the welfare level with mandatory disclosure to the first-best welfare level. The comparison is summarized in the following proposition.

Proposition 1: In both the Remediation case and the Improvement case, Mandatory Disclosure does not achieve the first-best social welfare level: $\forall \sigma \in \{L, H\}$ $W^{MD}(\sigma) < W^*(\sigma)$.

This inefficiency result contrasts with the efficiency result in the symmetric information case (where $\alpha = \frac{1}{2}$; see Shavell 1994). In the symmetric information case, the private value of information with MD is equal to the social value of information and, consequently, MD achieves the first-best social welfare level.

3.2 Voluntary Disclosure

The incentive to investigate is determined by the private value of information. In the Remediation case, we have: $I^{VD}(L) = (1 - \alpha)(v_H - \pi_S^{VD})$ for type L sellers, and $I^{VD}(H) = \alpha(v_H - \pi_S^{VD})$ for type H sellers. And, in the Improvement case, we have: $I^{VD}(L) = (1 - \alpha)(v_H + \Delta\tilde{v} - \pi_S^{VD})$ for type L sellers, and $I^{VD}(H) = \alpha(v_H + \Delta\tilde{v} - \pi_S^{VD})$ for type H sellers. Also recall that the expected profit of a seller who does not investigate is: $\pi_S^{VD} = \theta_L^{VD}\bar{v}_L + \theta_H^{VD}\bar{v}_H + (1 - \theta_L^{VD} - \theta_H^{VD})v_L$.

We compare the private value of information to the social value of information. In the Remediation case, we find that, for type H sellers, the private value of information is

higher than its social value; whereas, for type L sellers, the private value of information can be either higher or lower than its social value. In the Improvement case, we find that the private value of information is higher than its social value for both type H sellers and type L sellers.

These results are stated in the following lemma.

Lemma 2:
(a) In the Remediation case: (1) $I^{VD}(H) > I^*(H)$, and (2) $I^{VD}(L)$ can be either larger or smaller than $I^*(L)$.
(b) In the Improvement case: (1) $I^{VD}(H) > I^*(H)$, and (2) $I^{VD}(L) > I^*(L)$.

Remediation investments create social value in bad realizations (when the asset is of low value). This social value is equal to the investment value – the value from remediation. Private incentives to investigate, on the other hand, are driven by the higher price that Seller can get, when the investigation reveals a good realization. This higher price reflects the benefit from avoiding pooling with silent sellers; it does not reflect the investment value (since there is no remediation investment following a disclosure that the asset is of high value). For type H sellers, the expected benefit from avoiding pooling is relatively large (because they are more likely to get good news and separate via disclosure), and it always exceeds the investment value. For type L sellers, the expected benefit from avoiding pooling is relatively small (because they are less likely to get good news and separate via disclosure), and it can be either larger or smaller than the investment value

Improvement investments create social value in good realizations (when the asset is of high value). This social value equals to the investment value – the value from improving the asset. Private incentives to investigate are also driven by the higher price that Seller can get, when the investigation reveals a good realization. This higher price reflects both the investment value (learning that the asset is of high value triggers improvement investment) and the benefit from avoiding pooling with silent sellers. Because of this additional benefit, the private incentives always exceed the social value.

Multiple equilibria. The game defined by the VD rule can have multiple equilibria. As with MD, there can be a "high equilibrium," where many type H sellers investigate, and there can also be a "low equilibrium," where few type H sellers investigate.

In the Remediation case, the social welfare level is:

$$W^{VD}(\sigma) = \int_0^{I^{VD}(\sigma)} (\bar{v}_\sigma - k)\, f(k)\, dk + \left(1 - F\left(I^{VD}(\sigma)\right)\right) \bar{v}_\sigma = \bar{v}_\sigma - \int_0^{I^{VD}(\sigma)} k\, f(k)\, dk$$

where $\sigma \in \{L, H\}$. Investigation has no social value, since buyers never invest in remediation. Any investigation is, therefore, socially wasteful. In addition, opportunities for socially beneficial remediation are lost. In the Improvement case, the social welfare level is:

$$W^{VD}(\sigma) = \bar{v}_\sigma + \int_0^{I^{VD}(\sigma)} (I^*(\sigma) - k)\, f(k)\, dk$$

The welfare function resembles the first-best welfare function, albeit with a different investigation threshold. Investigation creates social value when it reveals good news. The seller discloses this good news, enabling efficient improvement investment.

Comparing the welfare level with voluntary disclosure to the first-best welfare level, we obtain the following result.

Proposition 2: In both the Remediation case and the Improvement case, Voluntary Disclosure does not achieve the first-best social welfare level: $\forall \sigma \in \{L, H\}$ $W^{VD}(\sigma) < W^*(\sigma)$.

3.3 Comparison: Mandatory Disclosure vs. Voluntary Disclosure

For both type H and type L sellers, we obtain the intuitive result that the private value of information with voluntary disclosure is larger than the private value of information with mandatory disclosure. Taken together with the results from Lemma 1 and Lemma 2, we obtain:

Lemma 3:

(a) In the Remediation case: (1) $I^*(H) < I^{MD}(H) < I^{VD}(H)$, and (2) $I^{MD}(L) < I^*(L) < I^{VD}(L)$ or $I^{MD}(L) < I^{VD}(L) < I^*(L)$.

(b) In the Improvement case: (1) $I^*(H) < I^{MD}(H) < I^{VD}(H)$, and (2) $I^{MD}(L) < I^*(L) < I^{VD}(L)$.

Multiple equilibria. As noted above, the games defined by both MD and VD can have multiple equilibria. In theory, it is possible to select a "high equilibrium," with a high $I^{MD}(\sigma)$, in the MD game, and a "low equilibrium," with a low $I^{VD}(\sigma)$, in the VD game, such that $I^{MD}(\sigma) > I^{VD}(\sigma)$. We rule out this possibility by focusing on comparsions between corresponding equilibria, e.g. between a high MD equilibrium and a high VD equilibrium. This equilibrium selection can be justified through the following dynamic reasoning: Assume an MD equilibrium (either a high MD equilibrium or a low MD equilibrium), with an equilibrium number of type H sellers who decided to investigate and an equilibrium number of type L sellers who decided to investigate, and where parties hold equilibrium expectations about these numbers of type H sellers and type L sellers who decided to investigate. Now consider new legislation that replaces the MD rule with a VD rule. The next seller – type H or type L – who makes a decision whether or not to investigate will have a negligible effect on the overall share of investigating sellers – on the share of investigating type H sellers or on the share of investigating type L sellers – and thus on parties' beliefs about these shares. Taking these beliefs as given, the new VD rule will necessarily increase the seller's incentive to investigate. Similar reasoning applies to the second seller (after the rule change) who decides whether or not to investigate, and to the third, and so on. Over time, the shares of type H sellers and of type L sellers who decide to investigate, and expectations about these shares, change, until a new VD equilibrium is reached.

We next compare welfare levels. Starting with type H sellers, Table 1 summarizes the welfare outcomes for each rule, and the first-best welfare outcome, as a function of investigation costs. And Figure 1 compares these welfare outcomes graphically. We see that, for type H sellers, MD is more efficient than VD – in both the Remediation case and

the Improvement case – for every level of investigation costs, and thus for any distribution of investigation costs.

		Remediation Case	Improvement Case
First-Best	$k < I^*(H)$	$W^*(H) = \bar{v}_H + (1-\alpha)\Delta\tilde{v} - k$	$W^*(H) = \bar{v}_H + \alpha\Delta\tilde{v} - k$
	$k \geq I^*(H)$	$W^*(H) = \bar{v}_H$	$W^*(H) = \bar{v}_H$
MD	$k < I^{MD}(H)$	$W^{MD}(H) = \bar{v}_H + (1-\alpha)\Delta\tilde{v} - k$	$W^{MD}(H) = \bar{v}_H + \alpha\Delta\tilde{v} - k$
	$k \geq I^{MD}(H)$	$W^{MD}(H) = \bar{v}_H$	$W^{MD}(H) = \bar{v}_H$
VD	$k < I^{VD}(H)$	$W^{VD}(H) = \bar{v}_H - k$	$W^{VD}(H) = \bar{v}_H + \alpha\Delta\tilde{v} - k$
	$k \geq I^{VD}(H)$	$W^{VD}(H) = \bar{v}_H$	$W^{VD}(H) = \bar{v}_H$

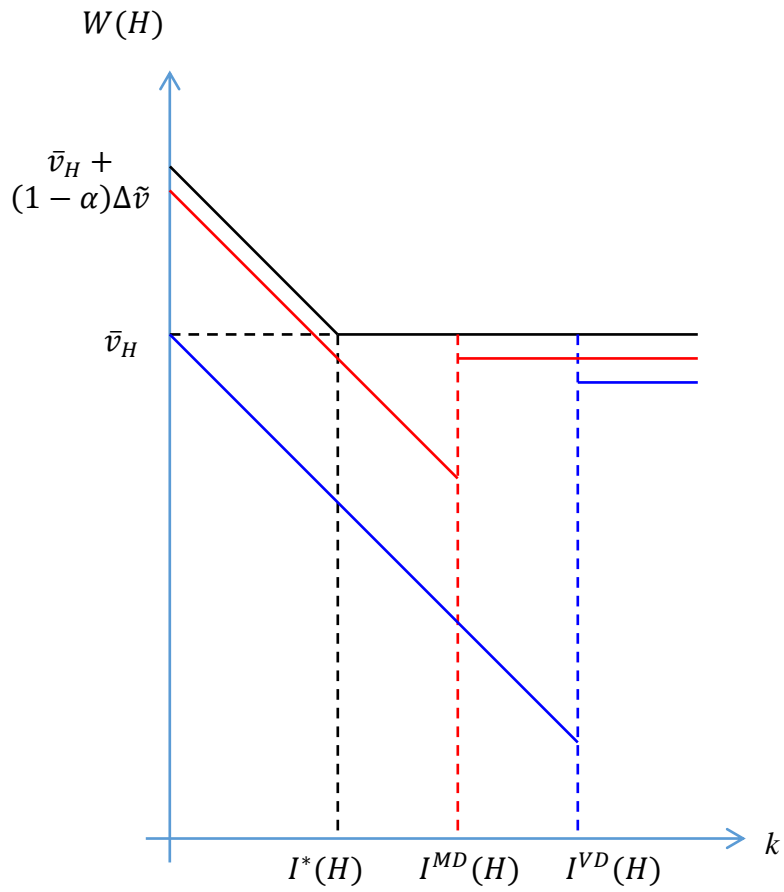Table 1: Welfare Outcomes for Type H Sellers

Figure 1a: Welfare Outcomes for Type H Sellers –
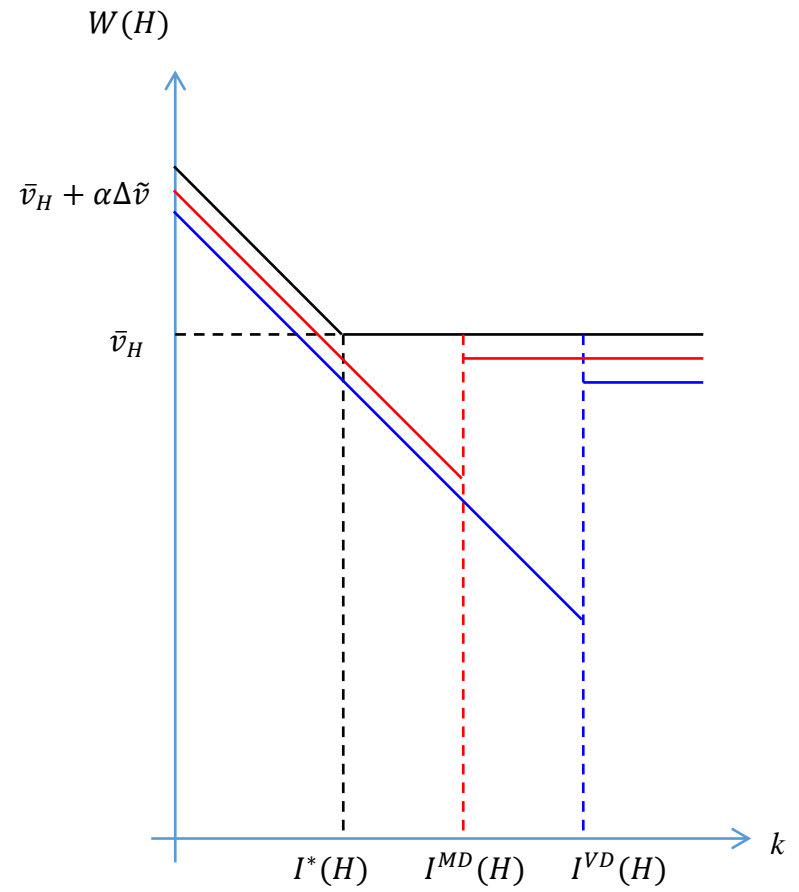Remediation Case
[Black: First-Best; Red: MD; Blue: VD]

Figure 1b: Welfare Outcomes for Type H Sellers –
Improvement Case
[Black: First-Best; Red: MD; Blue: VD]

Turning to type L sellers, Table 2 summarizes the welfare outcomes for each rule, and the first-best welfare outcome, as a function of investigation costs. And Figure 2 compares these welfare outcomes graphically.

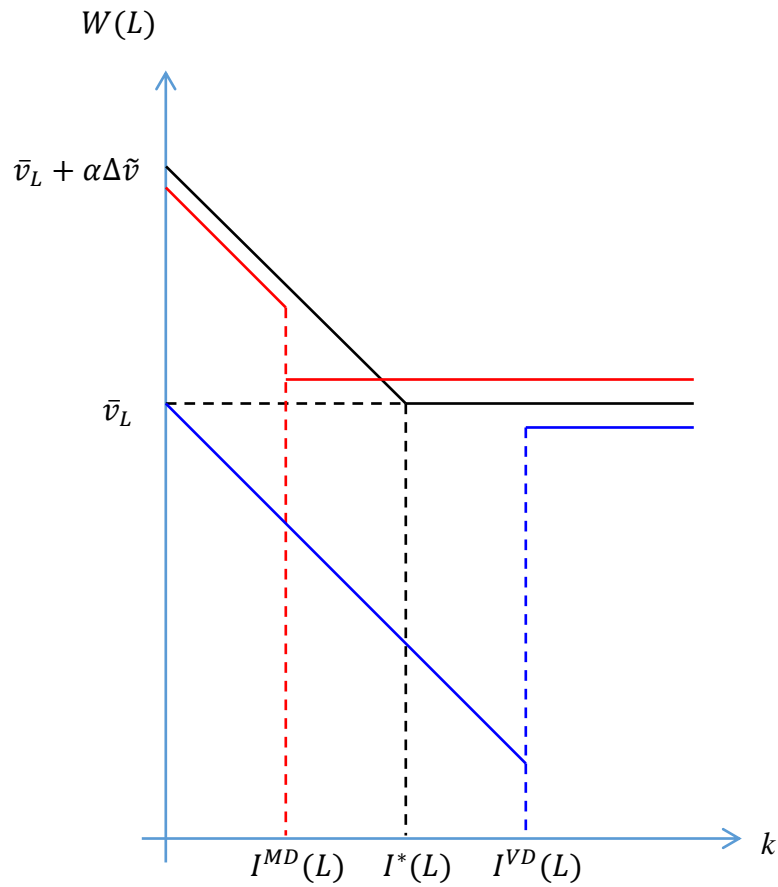|		Remediation Case	Improvement Case
First-Best	$k < I^*(L)$	$W^*(L) = \bar{v}_L + \alpha\Delta\tilde{v} - k$	$W^*(L) = \bar{v}_L + (1-\alpha)\Delta\tilde{v} - k$
	$k \geq I^*(L)$	$W^*(L) = \bar{v}_L$	$W^*(L) = \bar{v}_L$
MD	$k < I^{MD}(L)$	$W^{MD}(L) = \bar{v}_L + \alpha\Delta\tilde{v} - k$	$W^{MD}(L) = \bar{v}_L + (1-\alpha)\Delta\tilde{v} - k$
	$k \geq I^{MD}(L)$	$W^{MD}(L) = \bar{v}_L$	$W^{MD}(L) = \bar{v}_L$
VD	$k < I^{VD}(L)$	$W^{VD}(L) = \bar{v}_L - k$	$W^{VD}(L) = \bar{v}_L + (1-\alpha)\Delta\tilde{v} - k$
	$k \geq I^{VD}(L)$	$W^{VD}(L) = \bar{v}_L$	$W^{VD}(L) = \bar{v}_L$

Table 2: Welfare Outcomes for Type L Sellers

Figure 2a(i): Welfare Outcomes for Type L Sellers –
Remediation Case, with $I^{MD}(L) < I^*(L) < I^{VD}(L)$
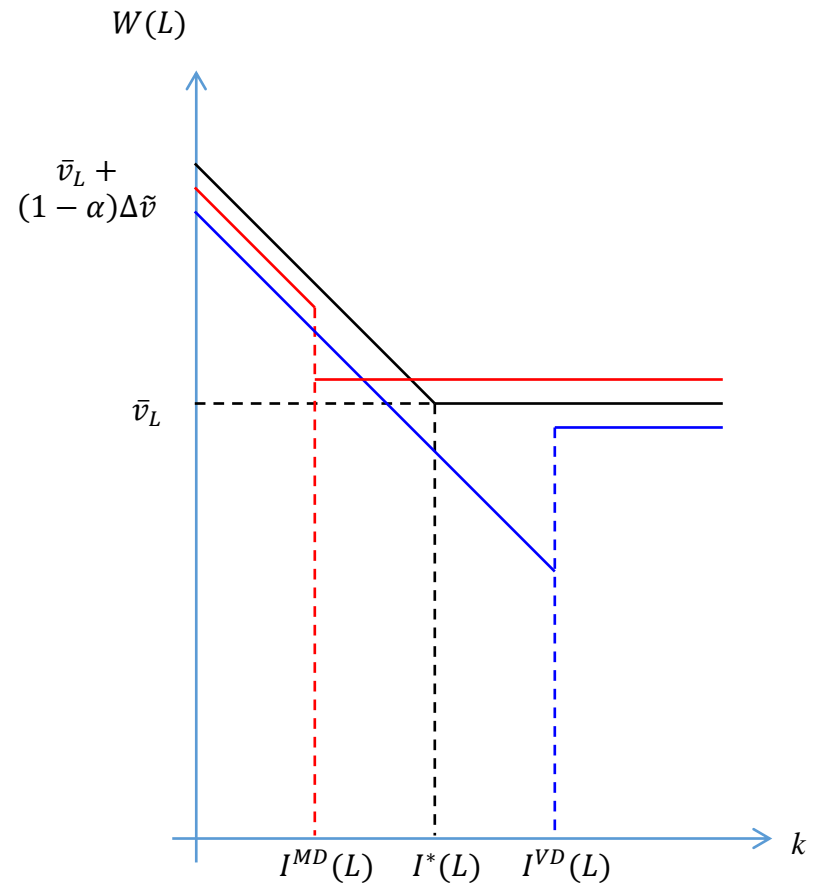[Black: First-Best; Red: MD; Blue: VD

Figure 2b: Welfare Outcomes for Type L Sellers –
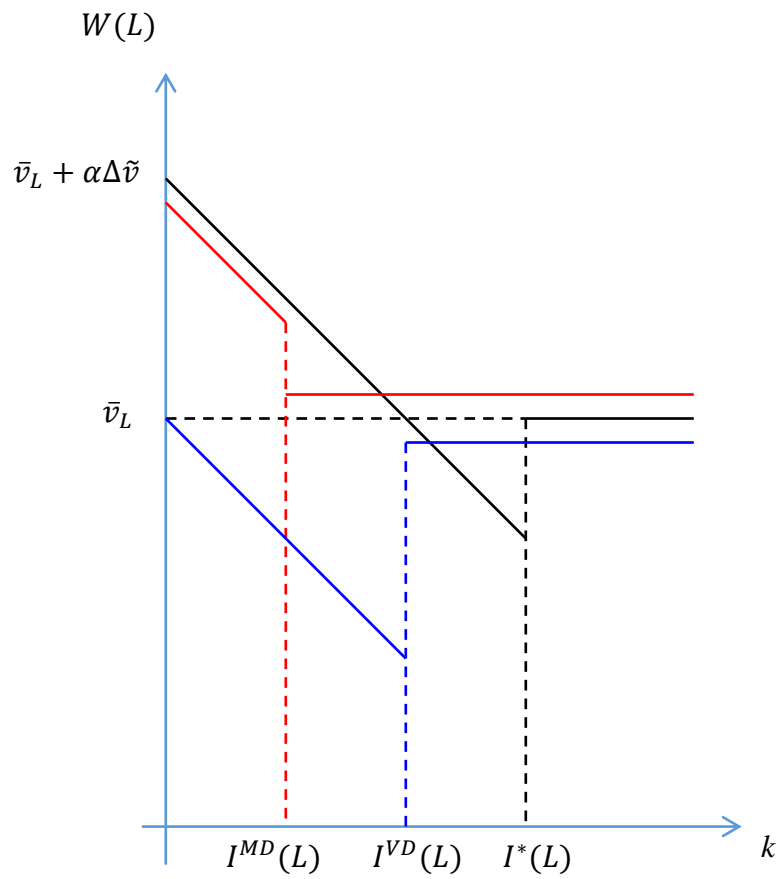Improvement Case
[Black: First-Best; Red: MD; Blue: VD]

$W(L)$

Figure 2a(ii): Welfare Outcomes for Type L Sellers –
Remediation Case, with $I^{MD}(L) < I^{VD}(L) < I^*(L)$
[Black: First-Best; Red: MD; Blue: VD]

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For type L sellers, the comparison between the two rules critically depends on the type of investment. In the Remediation case, MD is more efficient than VD – for every level of investigation costs, and thus for any distribution of investigation costs. In the Improvement case, on the other hand, MD is more efficient when $k \in [I^*(L), I^{VD}(L)]$, and VD is more efficient when $k \in [I^{MD}(L), I^*(L)]$. Therefore, for type L sellers, either rule can be more efficient, depending on the distribution of investigation costs.

Combining the results obtained for the two seller types, we can now proceed to an overall comparison of the two rules. In our framework, half of the sellers are type H and half are type L. Therefore, overall welfare is a simple average of the type H welfare and the type L welfare. In the Remediation case, MD dominates VD for both type H sellers and type L sellers, and so MD is the more efficient rule overall. In the Improvement case, MD has two advantages: (1) for type H sellers in the $[I^{MD}(H), I^{VD}(H)]$ range, and (2) for type L sellers in the $k \in [I^*(L), I^{VD}(L)]$ range. And VD has an advantage for type L sellers in the $k \in [I^{MD}(L), I^*(L)]$ range. Depending on the distribution function, $F(\cdot)$, either MD or VD can be the more efficient rule.

These results are summarized in the following proposition.

Proposition 3:

    (a) In the Remediation case: MD is more efficient than VD.

    (b) In the Improvement case: Either MD or VD can be the more efficient rule.

Proposition 3 contrasts with the clear dominance of MD in the symmetric information case (where $\alpha = \frac{1}{2}$; see Shavell 1994). In the symmetric information case, MD induces the first-best welfare level and is, therefore, always more efficient than VD. In the asymmetric information case, MD no longer achieves the first-best (see Proposition 1 above) and thus can be less efficient than VD.

4. Investment without Investigation

So far we have assumed that value-enhancing investment – in both the Remediation case and the Improvement case – can only occur post-investigation. In some cases, however, it may be possible to invest without prior-investigation. For example, if the probability of a termite infestation is large enough, an owner could treat the entire property for termites without a prior-investigation that establishes for sure the existence, or absence, of termites and pinpoints the source of the problem.

The possibility of investment without investigation can change the first-best outcome. In particular, when the investment yield, $\Delta v/x$, is sufficiently high and investigation costs are sufficiently large, it would be socially desirable to invest without prior investigation. In this case, the social value of information derives from the avoidance of unnecessary investment. In the Remediation case, we get $I^*(L) = (1 - \alpha)x$ and $I^*(H) = \alpha x$. And in the Improvement case, we get: $I^*(L) = \alpha x$ and $I^*(H) = (1 - \alpha)x$.

The possibility of investment without investigation can also change the payoff of a silent seller, since buyers facing a silent seller may decide to invest (without investigating). The question then becomes whether a buyer who faces a silent seller will invest or not. Consider the MD rule. A non-investing buyer gets $\theta_L^{MD} \bar{v}_L + \theta_H^{MD} \bar{v}_H$. In the Remediation case, an investing buyer gets $\theta_L^{MD}(\bar{v}_L + \alpha \Delta v) + \theta_H^{MD}(\bar{v}_H + (1 - \alpha)\Delta v) - x = \theta_L^{MD} \bar{v}_L + \theta_H^{MD} \bar{v}_H + (\theta_L^{MD} \alpha + \theta_H^{MD}(1 - \alpha))\Delta v - x$. And in the Improvement case, an investing buyer gets $\theta_L^{MD}(\bar{v}_L + (1 - \alpha)\Delta v) + \theta_H^{MD}(\bar{v}_H + \alpha \Delta v) - x = \theta_L^{MD} \bar{v}_L + \theta_H^{MD} \bar{v}_H + (\theta_L^{MD}(1 - \alpha) + \theta_H^{MD} \alpha)\Delta v - x$. We can similarly derive the payoffs of an investing buyer under the VD rule. When the investment yield, $\Delta v/x$, is sufficiently large, a buyer who faces a silent seller will choose to invest.

A buyer who faces a silent seller will choose to invest only when such investment increases her payoff. This also means that the buyer will be willing to pay a higher price to the silent seller. And when the payoff of a silent seller increases, the private value of information decreases. While both the social value of information and the private value of information may change when it is possible to invest without investigating, the basic results derived in Section 3 continue to hold. Specifically, the ordering results in Lemma

3 continue to hold. And the welfare comparison between MD and VD, as stated in Proposition 3, continues to hold.

Still, there is one subtle difference that is worth noting. Consider the Remediation case. Assume that the investment yield is not sufficiently high to affect the social value of information or to justify investment without investigation under MD, but high enough to justify investment without investigation under VD (under VD the group of silent seller could contain many investigating sellers who received bad news and so it is more likely that the buyer would chose to invest). Such investment can increase welfare under VD.

Specifically: For type H sellers, the VD row in Table 1 changes. For $k < I^{VD}(H)$, type H sellers investigate: A type H seller who investigated and learned that the asset value is high would voluntarily disclose the information; a type H seller who investigated and learned that the asset value is low would remain silent, and a buyer facing such a silent seller would invest in remediation. We thus have: $W^{VD}(H) = \bar{v}_H + (1 - \alpha)\Delta\tilde{v} - k$. For $k > I^{VD}(H)$, type H sellers do not investigate and thus necessarily remain silent. Buyers then invest in remediation. We thus have: $W^{VD}(H) = \bar{v}_H + (1 - \alpha)\Delta\tilde{v} - \alpha x$. Similarly, for type L sellers, the VD row in Table 2 changes. For $k < I^{VD}(L)$, we have: $W^{VD}(L) = \bar{v}_L + \alpha\Delta\tilde{v} - k$; and for $k > I^{VD}(L)$, we have: $W^{VD}(L) = \bar{v}_L + \alpha\Delta\tilde{v} - (1 - \alpha)x$. For type H sellers, MD dominates VD, as in the basic model. For type L sellers, MD is more efficient when $k > I^*(L)$, and VD is more efficient when $k \in [I^{MD}(L), I^*(L)]$. Still, it can be shown that MD is the most efficient rule overall, and Proposition 3 continues to hold.

To see why, consider (1) the range where VD holds an advantage for type L sellers $k \in [I^{MD}(L), I^*(L)]$, and (2) the range where MD holds an advantage for type H sellers $k > I^{MD}(H)$. (MD also holds an advantage for type L sellers, for $k \in [I^*(L), I^{VD}(L)]$, but we can ignore this for present purposes.) Since $I^*(L) < I^{MD}(H)$,[17] these two ranges are mutually exclusive. Wouldn't VD be the overall efficient rule, when the distribution of investigation costs has a large mass in the $[I^{MD}(L), I^*(L)]$ range and very little mass in the $(I^{MD}(H), \infty)$ range? The answer is no, because when there are only a few type H

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[17] Since $I^{MD}(L) < I^{MD}(H)$, we know that $\theta_L^{MD} \in \left[\frac{1}{2}, 1\right]$, and this implies $\pi_S^{MD} \leq \bar{v}$. Together with the low-yield investment assumption, $x > \alpha\Delta v$, and the assumption that remediation implies $\Delta v \leq v_H - v_L$, we get: $I^*(L) < I^{MD}(H)$.

sellers with investigation costs in the $(I^{MD}(H), \infty)$ range, then with MD most non-investigating, silent sellers are type L, θ_L^{MD} approaches 1, π_S^{MD} approaches $\bar{v}_L$, $I^{MD}(L)$ approaches $I^*(L)$, and the range where VD holds an advantage vis-à-vis MD disappears. Intuitively, MD's disadvantage comes from an inefficient failure to investigate by type L sellers. This failure to investigate is motivated by the desire of type L sellers to pool with non-investigating, silent type H sellers. When there are only a few type H sellers that do not investigate and remain silent (i.e., when there are only a few sellers with $k > I^{MD}(H)$), the advantage of pooling with type H sellers goes down and with it the advantage of VD vis-à-vis MD.

5. Mandatory Post-Contract Disclosure

Section 3 focused on the two standard rules: mandatory disclosure (MD) and voluntary disclosure (VD). We now introduce a third rule: mandatory post-contract disclosure (MPCD). MPCD allows the seller to (voluntarily) choose whether to disclose the results of an investigation pre-contract but, if the seller chose not to disclose pre-contract, the rule requires that she disclose post-contract. We show that this new rule can outperform the two standard rules. (We return to the basic model, from Section 3, where value-enhancing investments can occur only post-investigation.)

Our framework of analysis (Section 2) can be readily extended to include MPCD. Let π_S^{MPCD} denote the payoff of a silent seller in the MPCD regime. The no-investigation payoff is $\pi_{NI}^{MPCD}(\sigma) = \pi_S^{MPCD}$ (and is independent of seller type). Next consider the investigation payoff. In the Remediation case, we have: $\pi_I^{MPCD}(L) = (1 - \alpha)v_H + \alpha\pi_S^{MPCD}$ for type L sellers and $\pi_I^{MPCD}(H) = \alpha v_H + (1 - \alpha)\pi_S^{MPCD}$ for type H sellers. In the Improvement case, we have: $\pi_I^{MPCD}(L) = (1 - \alpha)(v_H + \Delta\tilde{v}) + \alpha\pi_S^{MPCD}$ for type L sellers and $\pi_I^{MPCD}(H) = \alpha(v_H + \Delta\tilde{v}) + (1 - \alpha)\pi_S^{MPCD}$ for type H sellers. The $\pi_I^{MPCD}(\sigma)$ functions are similar to those derived for VD, subject to the different π_S, since in both regimes a seller who investigates and finds v_L will remain silent and get π_S.

We can now calculate the private value of information. In the Remediation case, we have: is $I^{MPCD}(L) = \pi_I^{MPCD}(L) - \pi_{NI}^{MPCD}(L) = (1 - \alpha)(v_H - \pi_S^{MPCD})$ for type L sellers,

and $I^{MPCD}(H) = \pi_I^{MPCD}(H) - \pi_{NI}^{MPCD}(H) = \alpha(v_H - \pi_S^{MPCD})$ for type H sellers. And in the Improvement case, we have: $I^{MPCD}(L) = \pi_I^{MPCD}(L) - \pi_{NI}^{MPCD}(L) = (1-\alpha)(v_H + \Delta\tilde{v} - \pi_S^{MPCD})$ for type L sellers, and $I^{MPCD}(H) = \pi_I^{MPCD}(H) - \pi_{NI}^{MPCD}(H) = \alpha(v_H + \Delta\tilde{v} - \pi_S^{MPCD})$ for type H sellers.

As with MD and VD, the expected payoff of a silent seller plays a central role in the analysis. This expected value depends on the equilibrium "mix" of silent sellers as characterized in Section 2.3. Let θ_L^{MPCD} and θ_H^{MPCD}, defined as in Section 2.3, denote the shares of non-investigating type L sellers and type H sellers, respectively, among all silent sellers. And let $1 - \theta_L^{MPCD} - \theta_H^{MPCD}$ denote the share of investigating sellers (who found v_L) among all silent sellers. An investigating seller who gets good news will disclose pre-contract. An investigating seller who gets bad news will only disclose post-contract. In the Remediation case, the buyer will wait and invest only if the post-contract disclosure reveals bad news. Therefore, the expected payoff of a silent seller is $\pi_S^{MPCD} = \theta_L^{MPCD}\bar{v}_L + \theta_H^{MPCD}\bar{v}_H + (1 - \theta_L^{MPCD} - \theta_H^{MPCD})(v_L + \Delta\tilde{v})$. In the Improvement case, the buyer will invest only if the seller reveals good news pre-contract. Therefore, the expected payoff of a silent seller is $\pi_S^{MPCD} = \theta_L^{MPCD}\bar{v}_L + \theta_H^{MPCD}\bar{v}_H + (1 - \theta_L^{MPCD} - \theta_H^{MPCD})v_L$.

We can now compare the private value of information to the social value of information. We find that the private value of information is higher than its social value, for both type H and type L sellers. These results are stated in the following lemma.

Lemma 4:

(a) In the Remediation case: (1) $I^{MPCD}(H) > I^*(H)$, and (2) $I^{MPCD}(L)$ can be either larger or smaller than $I^*(L)$.

(b) In the Improvement case: (1) $I^{MPCD}(H) > I^*(H)$, and (2) $I^{MPCD}(L) > I^*(L)$.

The social welfare level is:

$$W^{MPCD}(\sigma) = \bar{v}_\sigma + \int_0^{I^{MPCD}(\sigma)} (I_\sigma^* - k) f(k) dk$$

where $\sigma \in \{L, H\}$. The same welfare function applies in both the Remediation case and the Improvement case. In the Improvement case, value-enhancing investment occurs when the seller gets good news and discloses pre-contract. In the Remediation case, value-enhancing investment occurs when the seller gets bad news and discloses post-contract. Either way, all information, including bad news, is revealed and we get optimal investment whenever the seller investigates. The inefficiency with MPCD results from excessive (costly) investigation.

Comparing the welfare level with mandatory post-contract disclosure to the first-best welfare level, we obtain the following result.

Proposition 4: In both the Remediation case and the Improvement case, Mandatory Post-Contract Disclosure does not achieve the first-best social welfare level: $\forall \sigma \in \{L, H\}$ $W^{MPCD}(\sigma) < W^*(\sigma)$.

Like MD and VD, MPCD does not attain the first-best. It is useful to consider MPCD, because it can outperform the two standard rules. We begin the comparison of the three rules by considering the private value of information. For both type H and type L sellers, we obtain the intuitive result that the private value of information with voluntary disclosure is larger than the private value of information with mandatory post-contract disclosure which is larger than the private value of information with mandatory (pre-contract) disclosure. Taken together with the results from Lemma 3, we obtain:

Lemma 5:
(a) In the Remediation case: (1) $I^*(H) < I^{MD}(H) < I^{MPCD}(H) < I^{VD}(H)$, *and (2)*
$I^{MD}(L) < I^{MPCD}(L) < I^*(L) < I^{VD}(L)$, $\quad I^{MD}(L) < I^*(L) < I^{MPCD}(L) < I^{VD}(L)$ *or*
$I^{MD}(L) < I^{MPCD}(L) < I^{VD}(L) < I^*(L)$.
(b) In the Improvement case: (1) $I^*(H) < I^{MD}(H) < I^{MPCD}(H) < I^{VD}(H)$, *and (2)*
$I^{MD}(L) < I^*(L) < I^{MPCD}(L) < I^{VD}(L)$.

We next compare welfare levels. Starting with type H sellers, Table 1a adds the welfare outcome for MPCD to Table 1.

		Remediation Case	Improvement Case
MPCD	$k < I^{MPCD}(H)$	$W^{MPCD}(H) = \bar{v}_H + (1 - \alpha)\Delta\tilde{v} - k$	$W^{MPCD}(H) = \bar{v}_H + \alpha\Delta\tilde{v} - k$
	$k \geq I^{MPCD}(H)$	$W^{MPCD}(H) = \bar{v}_H$	$W^{MPCD}(H) = \bar{v}_H$

Table 1a: Welfare Outcomes for Type H Sellers (MPCD)

Turning to type L sellers, Table 2a adds the welfare outcome for MPCD to Table 2.

		Remediation Case	Improvement Case
MPCD	$k < I^{MPCD}(L)$	$W^{MPCD}(L) = \bar{v}_L + \alpha\Delta\tilde{v} - k$	$W^{MPCD}(L) = \bar{v}_L + (1 - \alpha)\Delta\tilde{v} - k$
	$k \geq I^{MPCD}(L)$	$W^{MPCD}(L) = \bar{v}_L$	$W^{MPCD}(L) = \bar{v}_L$

Table 2a: Welfare Outcomes for Type L Sellers (MPCD)

In both the Remediation case and the Improvement case, we find that – for type H sellers, MPCD is more efficient than VD, but less efficient than MD; and for type L sellers, MPCD is more efficient than VD, and either more or less efficient than MD. Proceeding to the overall comparison, MPCD is more efficient than VD and be either more or less efficient than MD. These results are summarized in the following proposition.

Proposition 5: In both the Remediation case and the Improvement case, MPCD is more efficient than VD, and can be either more or less efficient than MD.

We see that, under certain considitions, the new, MPCD rule is more efficient than the two standard rules.[18]

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[18] MPCD may be more efficient than MD also when investment is possible without investigation (see Section 4). Consider the Remediation case and recall the reason why MD dominated VD. MD had a disadvantage for type L sellers, because it resulted in an inefficient failure to investigate by these sellers. The type L sellers failed to investigate, recall, because they wanted to pool with non-investigating type H

6. Concluding Remarks

6.1 Other Legal Rules

What if a buyer who learns, post sale, that the value of the asset is v_L can rescind the contract, regardless of whether the seller knew or investigated? This alternative rule resembles a strict liability (SL) regime. With SL, when the value of the asset is v_L, the buyer will eventually learn this information and then, using the threat of rescission, force the seller to return any payment above the asset's true value. This means that the seller has no reason to withhold bad news and, in the Remediation case, the seller has an affirmative reason to disclose bad news – to enable remediation investment (and thus get a higher price). And so an investigating seller discloses everything, as with MD. But MD does not induce optimal investigation, because of the asymmetric information problem. SL overcomes the asymmetric information problem by allowing the buyer to rescind the contract whenever he learns the bad news, even if the information arrives long after the contract was signed. Thus, SL induces optimal investigation.

Consider the Remediation case (a similar analysis applies to the Improvement case). The expected profit of a type L seller who investigates, but does not disclose bad news, is: $\pi_I^{SL}(L) = (1 - \alpha)v_H + \alpha v_L = \bar{v}_L$. If the type L seller investigates and discloses bad news (as well as good news), her expected profit is: $\pi_I^{SL}(L) = (1 - \alpha)v_H + \alpha(v_L + \Delta\tilde{v}) = \bar{v}_L + \alpha\Delta\tilde{v}$. Therefore, a type L seller who investigates will disclose bad news and get: $\pi_I^{SL}(L) = \bar{v}_L + \alpha\Delta\tilde{v}$. Similarly, a type H seller who investigates will disclose bad news and get: $\pi_I^{SL}(H) = \alpha v_H + (1 - \alpha)(v_L + \Delta\tilde{v}) = \bar{v}_H + (1 - \alpha)\Delta\tilde{v}$. A seller who chooses to investigate will disclose both good and bad news, even if there is

sellers. So MD's disadvantage for type L sellers relied on the existence of a sufficiently large number of non-investigating type H sellers, namely type H sellers with $k > I^{MD}(H)$. But when enough type H sellers have high investigation costs ($k > I^{MD}(H)$), MD's disadvantage for type L sellers is outweighed by its advantage for the type H sellers with $k > I^{MD}(H)$: avoiding excessive investigation for type H sellers with $k \in (I^{MD}(H), I^{VD}(H))$ and avoiding excessive remediation for type H sellers with $k > I^{VD}(H)$. Now compare MD to MPCD: MD has the same disadvantage vis-à-vis MPCD: it results in an inefficient failure to investigate by type L sellers. But now this disadvantage is not necessarily outweighed by MD's advantage for type H sellers. MD still avoids excessive investigation for type H sellers with $k \in (I^{MD}(H), I^{MPCD}(H))$, but MPCD avoids the excessive remediation problem for type H sellers with $k > I^{MPCD}(H)$. Therefore, when the distribution of investigation costs has a large mass both in the $k \in (I^{MD}(L), I^*(L))$ range and in the $k > I^{MPCD}(H)$ range, MPCD can be more efficient than MD.

no legal duty to disclose. (There is no point in withholding bad news from the buyer, since the buyer will eventually learn that the value of the asset is v_L and rescind the contract unless the price is not reduced accordingly.) The expected profit of a type L seller who does not investigate is $\pi_{NI}^{SL}(L) = (1-\alpha)v_H + \alpha v_L = \bar{v}_L$, and the expected profit of a type H seller who does not investigate is $\pi_{NI}^{SL}(H) = \alpha v_H + (1-\alpha)v_L = \bar{v}_H$. Therefore, the private value of information is $I^{SL}(L) = \pi_I^{SL}(L) - \pi_{NI}^{SL}(L) = \alpha\Delta\tilde{v}$ for type L sellers and $I^{SL}(H) = \pi_I^{SL}(H) - \pi_{NI}^{SL}(H) = (1-\alpha)\Delta\tilde{v}$ for type H sellers. We see that $I^{SL}(L) = I^*(L)$ and $I^{SL}(H) = I^*(H)$. Strict liability achieves the first-best investigation levels, and the first-best welfare levels.

But a strict liability rule is not without cost. SL, in essence, forces the seller to provide a broad warranty – a warranty that would also cover problems and risks that the seller could not have discovered through investigation. Such a mandatory warranty intervenes with the contractually specified risk allocation or, more precisely, prevents the parties from allocating risk as they see fit. (A similar analysis applies to voluntary warranties. See Section 1.4 above.)

In addition to the strict liability rule, it is also possible to envision a negligence rule, where the buyer's right to rescind the contract arises only if the seller was negligent in her decision to remain uninformed (or if the seller investigated but failed to disclose bad news). Doctrinally, such a rule would impose liability on a seller who "should have known" about the asset's condition.[19] In our framework, liability would be imposed, if a seller with $k < I^*(\sigma)$ ($\forall\sigma \in \{L, H\}$) failed to investigate. In theory, such a negligence rule can achieve the first-best investigation levels, and the first-best welfare levels. In practice, however, courts are unlikely to have the information required to implement a

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[19] *See, e.g.,* Ralbovsky v. Lamphere, 731 F. Supp. 79 (N.D.N.Y 1990) (holding that a seller of a used car reporting that the mileage shown on the odometer is true, may be held liable in the absence of actual knowledge that an odometer reading is false, if he reasonably should have known that the odometer reading was incorrect); Easton v. Strassburger, 199 Cal. Rptr. 383, 388 (Cal. App. 1st Dist. 1984) (holding that a broker is under a duty to disclose material facts which he should have known); Bradbury v. Rentz, Ohio App. LEXIS 9780 (1984) ("a failure to state a fact is equivalent to a fraudulent concealment when the seller knew of or in the exercise of reasonable diligence should have known of the presence of this material fact, and further knew or should have known that this material fact may have affected the action of the buyer"). *But see* Jacobson v. Sweeney, 82 F. Supp. 2d 458, 462 n.2 (D. Md. 2000) ("Real estate agents owe property buyers a duty, in some circumstances, to disclose defects of which they know or should have known, but recent cases have limited this duty to the disclosure of material facts known to the seller's agent"); Eric T. Freyfogle, *Real Estate Sales and the New Implied Warranty of Lawful Use*, 71 CORNELL L. REV. 1, 25-28 (1985) ("Sellers generally need disclose only matters of which they have some degree of personal knowledge").

negligence rule. Specifically, the optimal due care standard, $I^*(\sigma)$, is a function of the seller's type (type L or type H), which will generally be non-verifiable.

6.2 Investigation by the Buyer

This paper studies the seller's investigation decision and how it is affected by different disclosure rules. In some cases, the buyer can also investigate (pre-contract). A full analysis of this sequential investigation game is beyond the scope of this paper. We can, however, offer a few observations: Since investigation by the seller and investigation by the buyer are substitutes, it is efficient that only one party investigate. If the timing of the investigation is not crucial, then the party with the lower investigation costs should investigate. In many cases, however, early investigation is desirable. In the Remediation case, early investigation is desirable, when remediation costs increase with time. And in the Improvement case, early investigation is desirable, when some investment opportunities are time sensitive. Therefore, investigation by the seller – perhaps years before the sale – is often more efficient. In addition, the seller will generally have private information that allows for more efficient, focused investigation. For example, a seller who suspects underground water will investigate this particular problem, whereas an investigation by an uninformed buyer would have to be broader and more expensive. The timing and information considerations provide further justification for our focus on the seller's investigation decision.

The possibility of investigation by the buyer creates another type of efficiency cost: duplicative investigation. This problem arises with VD (and also with MPCD), where an investigating seller might remain silent and thus trigger duplicative investigation by the buyer.[20]

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[20] In the Remediation case, when investment without investigation is possible, the possibility of investigation by the buyer reduces the cost of indiscriminate remediation. In particular, we saw in Section 4 that, with VD, a buyer who faces a silent seller might choose to invest in remediation, since the probability of low value is sufficiently high. When the value of the asset is high (and the seller was silent simply because she chose not to investigate), the remediation would be wasteful. When the buyer can investigate, he may choose to do so, rather than engage in indiscriminate remediation.

6.3 Other Applications

We have focused on investigation by an owner who anticipates a (possible) future sale of the asset. But our model also applies, with appropriate adjustments, to another important set of cases: an owner who hires a contractor, or other service provider, to perform work on the asset. For example, consider a landowner who hires a contractor to build a house on the property or to perform some renovations or improvements on an existing house. Adapting our model to such applications, we would replace the value of the asset to the buyer $v \in \{v_L, v_H\}$ with the cost of performing the work to the contractor $c \in \{c_L, c_H\}$.

Investigation would determine if, because of some hidden feature of the asset, the work would cost more to perform. For example, the geological conditions of the land might make it more costly to construct the house. The information unearthed by an investigation is, again, productive information and can lead to efficient remediation or mitigation. In particular, an owner who investigates and learns about the unfavorable geological conditions can take steps to reduce the cost of performance to the contractor. Or, the contractor, if informed about the unfavorable geological conditions can employ specialized equipment and hire specially trained workers. If the owner does not disclose the geological information, the value of the transaction will decrease: It will take time for the contractor to discover the geological challenges herself. Such delay might render the cost-reducing measures ineffective (or less effective). Or the contractor, after inefficiently initiating standard construction processes with standard equipment and non-specialized employees, would now have to reverse course and call for specialized equipment and employees.

The preceding analysis can be readily applied to these service contracts. And the results regarding the relative efficiency of the different disclosure rules would similarly apply.

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Appendix

Proof of Lemma 1: Immediate from the preceding analysis.

Proof of Proposition 1: Immediate from the preceding analysis.

Proof of Lemma 2

(a) The Remediation case: We show that $I^{VD}(H) \geq I^*(H)$. $I^*(H) = (1 - \alpha)\Delta\tilde{v}$ and $I^{VD}(H) = \alpha(v_H - \pi_S^{VD})$. Recall that $\Delta\tilde{v} < \pi_S^{VD} - v_L$ (otherwise VD converges to MD and we know, from Lemma 1, that $I^{MD}(H) \geq I^*(H)$). This means that $I^*(H) < (1 - \alpha)(\pi_S^{VD} - v_L)$. We show that: $I^{VD}(H) = \alpha(v_H - \pi_S^{VD}) > (1 - \alpha)(\pi_S^{VD} - v_L) > I^*(H)$. After some rearranging, $\alpha(v_H - \pi_S^{VD}) > (1 - \alpha)(\pi_S^{VD} - v_L)$ becomes: $\alpha(v_H - v_L) > (1 - \alpha)(\pi_S^{VD} - v_L)$, which is clearly satisfied (since $\pi_S^{VD} < v_H$ and $\alpha \geq \frac{1}{2}$).

(b) The Improvement case: We first show that $I^{VD}(H) \geq I^*(H)$. $I^*(H) = \alpha\Delta\tilde{v}$ and $I^{VD}(H) = \alpha(v_H + \Delta\tilde{v} - \pi_S^{VD})$. It is thus clear that: $I^*(H) = \alpha\Delta\tilde{v} \leq \alpha(v_H + \Delta\tilde{v} - \pi_S^{VD}) = I^{VD}(H)$. We next show that $I^{VD}(L) > I^*(L)$. $I^*(L) = (1 - \alpha)\Delta\tilde{v}$ and $I^{VD}(L) = (1 - \alpha)(v_H + \Delta\tilde{v} - \pi_S^{VD})$. It is thus clear that: $I^*(L) = (1 - \alpha)\Delta\tilde{v} \leq (1 - \alpha)(v_H + \Delta\tilde{v} - \pi_S^{VD}) = I^{VD}(L)$.

QED

Proof of Proposition 2: Immediate from the preceding analysis.

Proof of Lemma 3

(a) The Remediation case: We show that $I^{VD}(H) > I^{MD}(H)$ and $I^{VD}(L) > I^{MD}(L)$. In an MD equilibrium, we have: $I^{MD}(L) = \bar{v}_L + \alpha\Delta\tilde{v} - \pi_S^{MD}$ and $I^{MD}(H) = \bar{v}_H + (1 - \alpha)\Delta\tilde{v} - \pi_S^{MD}$, with corresponding beliefs: $\hat{I}^{MD}(L) = I^{MD}(L)$ and $\hat{I}^{MD}(H) = I^{MD}(H)$. Now the legislator replaces the MD rule with a VD rule. Initially, beliefs remain unchanged: $\hat{I}^{VD}(L) = \hat{I}^{MD}(L)$ and $\hat{I}^{VD}(H) = \hat{I}^{MD}(H)$, which also implies: $\hat{\theta}_L^{VD} = \hat{\theta}_L^{MD}$ and $\hat{\theta}_H^{VD} = \hat{\theta}_H^{MD}$. Since $\pi_S^{VD} = \hat{\theta}_L^{VD}\bar{v}_L + \hat{\theta}_H^{VD}\bar{v}_H + (1 - \hat{\theta}_L^{VD} - \hat{\theta}_H^{VD})v_L \leq \hat{\theta}_L^{VD}\bar{v}_L + \hat{\theta}_H^{VD}\bar{v}_H = \pi_S^{MD}$ (when $\hat{\theta}_L^{VD} = \hat{\theta}_L^{MD}$ and $\hat{\theta}_H^{VD} = \hat{\theta}_H^{MD}$), we can show that $I^{VD}(H) > I^{MD}(H)$

and $I^{VD}(L) > I^{MD}(L)$. We first establish that $I^{VD}(H) > I^{MD}(H)$ and $I^{VD}(L) > I^{MD}(L)$ when $\pi_S^{VD} = \pi_S^{MD}$ and then argue that $\pi_S^{VD} < \pi_S^{MD}$ only strengthens this result.

Assume that $\pi_S^{VD} = \pi_S^{MD} \equiv \pi_S$. Since $\Delta\tilde{v} < \pi_S - v_L$ (otherwise VD converges to MD), we know that $I^{MD}(H) = \bar{v}_H + (1-\alpha)\Delta\tilde{v} - \pi_S < \bar{v}_H + (1-\alpha)(\pi_S - v_L) - \pi_S = \alpha(v_H - \pi_S)$. Since $I^{VD}(H) = \alpha(v_H - \pi_S)$, we have $I^{VD}(H) > I^{MD}(H)$. We also know that $I^{MD}(L) = \bar{v}_L + \alpha\Delta\tilde{v} - \pi_S < \bar{v}_H + \alpha(\pi_S - v_L) - \pi_S = (1-\alpha)(v_H - \pi_S)$. Since $I^{VD}(L) = (1-\alpha)(v_H - \pi_S)$, we have $I^{VD}(L) > I^{MD}(L)$. And since both $I^{VD}(H)$ and $I^{VD}(L)$ are decreasing in π_S^{VD}, replacing $\pi_S^{VD} = \pi_S^{MD}$ with $\pi_S^{VD} < \pi_S^{MD}$ only strengthens these results.

We have shown that $I^{VD}(H) > I^{MD}(H)$ and $I^{VD}(L) > I^{MD}(L)$, when beliefs remain unchanged (after MD is replaced with VD), namely, when $\hat{I}^{VD}(L) = \hat{I}^{MD}(L)$ and $\hat{I}^{VD}(H) = \hat{I}^{MD}(H)$. Over time, beliefs will adjust to reflect the increased incentives to investigate under VD. This adjustment further reduces π_S^{VD} and thus further increases $I^{VD}(H)$ and $I^{VD}(L)$. (It can be readily confirmed that $\frac{\partial\pi_S^{VD}}{\partial\hat{I}^{VD}(L)} < 0$ and $\frac{\partial\pi_S^{VD}}{\partial\hat{I}^{VD}(H)} < 0$.)

Together with Lemma 1(a) and Lemma 2(a), this establishes that $I^*(H) < I^{MD}(H) < I^{VD}(H)$; and $I^{MD}(L) < I^*(L) < I^{VD}(L)$ or $I^{MD}(L) < I^{VD}(L) < I^*(L)$.

(b) The Improvement case: We show that $I^{VD}(H) > I^{MD}(H)$ and $I^{VD}(L) > I^{MD}(L)$. Again, we start with unchanged beliefs: $\hat{I}^{VD}(L) = \hat{I}^{MD}(L)$ and $\hat{I}^{VD}(H) = \hat{I}^{MD}(H)$. It can be readily shown that $I^{VD}(H) > I^{MD}(H)$ and $I^{VD}(L) > I^{MD}(L)$, if $\pi_S^{VD} = \pi_S^{MD} \equiv \pi_S$. And since both $I^{VD}(H)$ and $I^{VD}(L)$ are decreasing in π_S^{VD}, replacing $\pi_S^{VD} = \pi_S^{MD}$ with $\pi_S^{VD} < \pi_S^{MD}$ only strengthens these results. Over time, beliefs will adjust to reflect the increased incentives to investigate under VD. This adjustment further reduces π_S^{VD} and thus further increases $I^{VD}(H)$ and $I^{VD}(L)$. (It can be readily confirmed that $\frac{\partial\pi_S^{VD}}{\partial\hat{I}^{VD}(L)} < 0$ and $\frac{\partial\pi_S^{VD}}{\partial\hat{I}^{VD}(H)} < 0$.)

Together with Lemma 1(b) and Lemma 2(b), this establishes that $I^*(H) < I^{MD}(H) < I^{VD}(H)$ and $I^{MD}(L) < I^*(L) < I^{VD}(L)$.

QED

Proof of Proposition 3: Immediate from the preceding analysis.

Section 4

In the Remediation case, we prove that MD is more efficient than VD also when investment is possible without investigation. The welfare advantage of VD vis-à-vis MD w.r.t type L sellers equals:

$$W^{VD-MD}(L) = \int_{I^{MD}(L)}^{I^*(L)} (\bar{v}_L + \alpha \Delta \tilde{v} - k - \bar{v}_L) f(k) dk$$

Observe that

$$W^{VD-MD}(L) \le \left[F(I^*(L)) - F(I^{MD}(L)) \right] \cdot (\bar{v}_L + \alpha \Delta \tilde{v} - I^{MD}(L) - \bar{v}_L)$$
$$= \left[F(I^*(L)) - F(I^{MD}(L)) \right] \cdot (\pi_S^{MD} - \bar{v}_L)$$

And since $I^{MD}(H) > I^*(L)$ (since $I^{MD}(L) < I^{MD}(H)$, we know that $\theta_L^{MD} \in \left[\frac{1}{2}, 1 \right]$, and this implies $\pi_S^{MD} \le \bar{v}$; together with the low-yield investment assumption, $x > \alpha \Delta v$, and the assumption that remediation implies $\Delta v \le v_H - v_L$, we get: $I^*(L) < I^{MD}(H)$), we know that

$$W^{VD-MD}(L) \le \left[F(I^{MD}(H)) - F(I^{MD}(L)) \right] \cdot (\pi_S^{MD} - \bar{v}_L)$$
$$= \left[F(I^{MD}(H)) - F(I^{MD}(L)) \right] \cdot (1 - \theta_L^{MD})(2\alpha - 1)(v_H - v_L)$$

Let $max\langle W^{VD-MD}(L) \rangle = \left[F(I^{MD}(H)) - F(I^{MD}(L)) \right] \cdot (1 - \theta_L^{MD})(2\alpha - 1)(v_H - v_L)$ denote the largest possible advantage of VD.

The welfare advantage of MD vis-à-vis VD w.r.t type H sellers equals:

$$W^{MD-VD}(H) = \int_{I^{MD}(H)}^{I^{VD}(H)} \left(\bar{v}_H - (\bar{v}_H + (1-\alpha)\Delta \tilde{v} - k) \right) f(k) dk$$

$$+ \int_{I^{VD}(H)}^{\infty} \left(\bar{v}_H - (\bar{v}_H + (1-\alpha)\Delta \tilde{v} - \alpha x) \right) f(k) dk$$

(MD has further advantage w.r.t. type L sellers, which we are ignoring.)

Observe that

$$W^{MD-VD}(H) \geq \int_{I^{M\dot{D}}(H)}^{I^{VD}(H)} \left(\bar{v}_H - \left(\bar{v}_H + (1-\alpha)\Delta\tilde{v} - I^{MD}(H)\right)\right) f(k)dk$$

$$= \left[F\left(I^{VD}(H)\right) - F\left(I^{MD}(H)\right)\right] \cdot \left(\bar{v}_H - \left(\bar{v}_H + (1-\alpha)\Delta\tilde{v} - I^{MD}(H)\right)\right)$$

$$+ \left[1 - F\left(I^{VD}(H)\right)\right] \cdot \left(\bar{v}_H - \left(\bar{v}_H + (1-\alpha)\Delta\tilde{v} - \alpha x\right)\right)$$

Since $\alpha x > I^{MD}(H)$ (given the low-yield investment assumption, $x > \alpha\Delta v$, and the assumption that remediation implies $\Delta v \leq v_H - v_L$), we have:

$$W^{MD-VD}(H) \geq \left[1 - F\left(I^{MD}(H)\right)\right] \cdot \left(\bar{v}_H - \left(\bar{v}_H + (1-\alpha)\Delta\tilde{v} - I^{MD}(H)\right)\right)$$

$$= \left[1 - F\left(I^{MD}(H)\right)\right] \cdot (\bar{v}_H - \pi_S^{MD})$$

$$= \left[1 - F\left(I^{MD}(H)\right)\right] \cdot \theta_L^{MD}(2\alpha - 1)(v_H - v_L)$$

Let $\quad min\langle W^{MD-VD}(H)\rangle = \left[1 - F\left(I^{MD}(H)\right)\right] \cdot \theta_L^{MD}(2\alpha - 1)(v_H - v_L) \quad$ denote the smallest possible advantage of MD.

We will show that $\forall \theta_L^{MD} \in \left[\frac{1}{2}, 1\right]: min\langle W^{MD-VD}(H)\rangle > max\langle W^{VD-MD}(L)\rangle$. (Since there are equal numbers of type L sellers and type H sellers, we can compare the advantage of VD w.r.t. type L sellers with the advantage of MD w.r.t. type H sellers.) Specifically, we need to prove that:

$$\left[1 - F\left(I^{MD}(H)\right)\right] \cdot \theta_L^{MD}(2\alpha - 1)(v_H - v_L)$$

$$> \left[F\left(I^{MD}(H)\right) - F\left(I^{MD}(L)\right)\right] \cdot (1 - \theta_L^{MD})(2\alpha - 1)(v_H - v_L)$$

Recall that $\theta_L^{MD} = \frac{\left[1-F\left(I^{MD}(L)\right)\right]}{\left[1-F\left(I^{MD}(L)\right)\right]+\left[1-F\left(I^{MD}(H)\right)\right]}$. This implies that $\left[1 - F\left(I^{MD}(L)\right)\right] =$

$\frac{\theta_L^{MD}}{1-\theta_L^{MD}}[1 - F(I^{MD}H)]$ and that $F\left(I^{MD}(H)\right) - F\left(I^{MD}(L)\right) = \frac{2\theta_L^{MD}-1}{1-\theta_L^{MD}}[1 - F(I^{MD}H)]$.

Substituting into the preceding condition, we obtain:

$$\left[1 - F\left(I^{MD}(H)\right)\right] \cdot \theta_L^{MD}(2\alpha - 1)(v_H - v_L)$$
$$> \frac{2\theta_L^{MD} - 1}{1 - \theta_L^{MD}}[1 - F(I^{MD}H)] \cdot (1 - \theta_L^{MD})(2\alpha - 1)(v_H - v_L)$$

Or: $\theta_L^{MD} < 1$.

QED

Proof of Lemma 4: Similar to the proof of Lemma 2.

Proof of Proposition 4: Immediate from the preceding analysis.

Proof of Lemma 5: Similar to the proof of Lemma 2.

Proof of Proposition 5: Immediate from the preceding analysis.