Corporate Governance and Information Quality in Capital Markets

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ABSTRACT

Recent corporate governance reforms around the world are intended to promote market efficiency through increased public disclosure by firms. This paper develops a model of strategic investors to investigate how changes in corporate governance regulations affect the market's ability to process information acquired by different types of investors. These changes affect market liquidity, investors' trading behavior and the quality of information.

In equilibrium, we show that the market price reflects both the public report issued by the firm's manager and the private signals acquired by informed investors. We prove that, with many sources of information, disclosure regulation designed to improve information quality should account for both the direct and indirect effects due to the changing relationship among different types of traders. In the case where different information traders receive different signals, we show how the individual and collective decisions change as the correlation between signals changes.

This combination of effects is especially noteworthy when an investor's motivation is to gain "foreknowledge" as opposed to "discovering" something innovative. Using numerical simulations, we demonstrate that the effect of governance on total information quality varies with the characteristics of the market and provide examples of counter-intuitive net effects. We conclude with some empirical predictions and some implications relevant to policy makers and managers.

Keywords: corporate governance, information asymmetry, policy, information acquisition, insider trading

1. Introduction

Many people believe that stock market prices could reveal the value of a firm more accurately if managers disclosed more information. Many people also believe that this accuracy would benefit investors, firms and society. Recent corporate governance reforms around the world have used these beliefs to justify an increase in public disclosure by firms. While many researchers debate whether the total costs incurred by firms to organize the disclosed information exceed the social benefits, we explore the idea that the information used in a market comes from various sources. Using both formal analysis and numerical simulations, we show how a change in the disclosure regulations can change the interaction amongst different types of traders and, by changing the interaction, an increase in public disclosure has an ambiguous effect on the total informativeness of the stock price. We also show how changes in the trading environment or the information environment can magnify or shrink those effects.

Most analyses seem to be based on what the Security and Exchange Commission's (SEC) Chair calls the disinfecting power of sunlight: "What hasn't changed in 75 years is the importance of full disclosure– sunlight remains the best disinfectant for problems in our capital markets."[1] This position has much to recommend, especially in the context of resolving issues related to the principal-agent relationship. Disclosing more information may reduce the gap in knowledge amongst investors. Yet, investors live in an information-rich environment and not all of the information about a company comes from a single source (i.e., the company itself). Beyer et al. [2010, p. 300] note that "the vast majority of research … ignores [the] interdependencies [amongst earnings announcements, management disclosures, SEC filings and analyst forecasts]." We argue that this interdependence would be evident when the amount of information gathered privately varies with the amount of information disclosed publicly: in other words, we should recognize that sunlight can be reflected and magnified.

Many recent innovations have affected the disclosure process. Some have been initiated by regulators while others were the result of changes in information technology: for example,

- Regulation FD ("Fair Disclosure", implemented in 2000),

- Conference calls distributed through corporate websites which facilitate interaction between investment analysts and senior managers,

- The increasing popularity of investor-oriented websites (Antweiler and Frank [2004]),

[1] Christopher Cox, http://news.rutgers.edu/medrel/news-releases/2008/06/sec-chair-taps-rutge-20080626.

- The SEC's decision to publish many reports (such as 10-K reports) through EDGAR (soon to be replaced by IDEA[2]).

A recent report by Iannaconi [2011] documents the increase in the number of pages in a disclosure and the greater increase in the space devoted to footnotes. Perhaps a sign of the significance of the changes in disclosures is found in FASB's decision to create a Disclosure Committee which would, in part, discuss disclosure *overload*.[3]

To investigate these phenomena, we develop a strategic investor model based on Kyle [1985] with two disclosure regimes. Our theoretical model considers the behavior of four types of traders: a firm's manager (i.e., an insider), multiple privately informed rational investors, one privately uninformed rational investor called the "market maker", as well as liquidity traders. A corporate insider (i.e., executives, directors and employees) may trade for any of several reasons. When disclosure is limited, they may be able to also benefit from their access to detailed corporate information. Private investors and institutional investors may start with the publicly disclosed information but they also invest much time and effort to refine that information and to gather information from other sources. Based on the public report as well as inferences about the private information through the aggregated trading quantities, a privately uninformed investor ("market maker") decides how much to trade and the market price clears the market.

In equilibrium, we show that the market price reflects the public report fully and the private signals only partially. As is common in Kyle-type models, both the manager and informed investors anticipate that their informed decisions influence the market price, and act strategically. Therefore, instead of acting as a price taker, they maximize profits by restraining their trading activity and hiding their private information partially. This aspect is important because recent regulations have changed the distribution of information and the credibility of the information that is disclosed. Depending on the kind of disclosure regulation, and other corporate governance mechanisms, private information may be more or less valuable.

This more subtle effect influences the level of total information incorporated into the market price. If public and private information provide similar insights then making more information available publicly would decrease the effort expended by investors to acquire the

[2] "Interactive Data Electronic Applications" which is intended to be more user-friendly with more interactive features and simpler conversion from one format to another: http://idea.sec.gov/.

[3] http://www.fasb.org/cs/ContentServer?c=FASBContent_C&pagename=FASB/FASBContent_C/NewsPage&cid=1176156338441.

same information privately. More subtle issues can arise when, for example, public and private information complement each other: such as if private information is needed to interpret an otherwise ambiguous public disclosure, or if disclosing more information about a source of risk encourages an investor to research that dimension of the firm more carefully, or if disclosing more information on all firms encourages an investor to investigate the competitive aspects of a market, or if disclosing historic information offers limited insights into the future earnings of the company. We show that many results can be characterized using the value of a single parameter which measures the interaction between the disclosure and an informed investor's cost.

Our model also explores how access to information redistributes rents amongst traders without necessarily adding surplus value. Hirshleifer [1971] explores this tension between profit and social value when he distinguishes "foreknowledge", which can be individually profitable but not socially valuable, and "discovery", which is socially valuable (e.g., a new drug or technology) but which may or may not be profitable to the discoverer. More recently, Beyer et al. [2010] note that the competition may encourage sell-side stock market analysts to act as though they were in a race to be first with the information, as opposed to finding the most precise information or to discover something innovative.[4] Understanding the notion of rent shifting can be important for policy discussions because, as other authors have noted, a model's claim that a particular outcome is or is not efficient may not be robust (see, for example, Verrecchia [1982]). Even if it were robust, a simple finding of a market failure may not be sufficient to justify a particular regulation (e.g., Leuz and Wysocki [2008, p. 15]).

In an equilibrium, many forces must be balanced. Therefore, if the analysis overlooks one of the forces or it is assumed to be exogenous then a change in policy can have unintended consequences. We show when increased public disclosure leads to lower quality of private signals. This decrease could happen if, for one of several reasons, more informative public reports make it more costly for the investors to obtain additional information. In contrast, if the investors obtain private signals by processing public reports, then disclosing more information or more detailed information can reduce their total information costs. Even if public disclosure appears to have no effect on private information acquisition, perhaps because the different types of information are used to resolve different types of questions, disclosure can also change the

[4] Gao [2008] and James and Lawler [2011] note that the debate about the social value of public information is especially contentious in a "beauty contest" situation where the information may also act as a coordinating device on the actions of individuals. This issue may be more important in models which, unlike ours, display herd behaviour.

behavior of the market maker. For these reasons, the effects of better governance on total information quality and on price accuracy vary case by case. These differences may be evident in the differences between small and large companies within an industry, or between industries. The differences may also be evident between countries because the institutions which complement the financial markets may differ.

We are not the first to consider the effects of a disclosure regulation but, we suggest, our model offers several innovations.[5] McNichols and Trueman [1994], Lambert, Leuz, and Verrecchia [2007] and Lambert, Leuz, and Verrecchia [2008] consider equilibrium models showing how different types of investors adapt to information obtained from an independent source. Their models emphasize the role of statistical correlations between groups of firms in the context of a CAPM framework. They note that information has a direct effect, by revealing cash flow, and an indirect effect through the covariance with the cash flow and profits of other firms. These papers focus on how the interaction between public information disclosure and private information gathering changes the variance/covariance matrix of returns. We focus on the cost of gathering information and this difference matters because, independent of the net benefit to an average trader, trading behavior changes. Further, and unlike our model, these models assume that the cost of private information gathering is independent of the external environment. Chen, Cheng, and Lo [2010] examine the types of investigations conducted by analysts and show that reality is more complex.

Several researchers (Barron et al. [1998] and Gu [2005]) have created measures of public and private information quality that was used by other researchers to study how both can vary separately in response to a regulation. Mohanram and Sunder [2006] use these measures to investigate the effects of Regulation FD and find that, although managers disclosed information less frequently, stock market analysts appear to have acquired more private information from other sources: the overall information environment for analysts had *not* deteriorated. Begley, Cheng, and Gao [2011] use these measures to investigate the effects of the Sarbanes-Oxley Act and find that public and private information quality changed in opposite directions immediately afterward to produce an insignificant change in total information quality. Thus, history offers

[5] In addition, there is the large and important line of research which looks at the effects of disclosure on the agency relationship between shareholders and managers: see Adams, Hermalin, and Weisbach [2010] for an overview or Feltham and Wu [2000] for a discussion of how best to use the stock price as an additional performance measure in managing that relationship.

examples where it is important to consider how a policy can change both public and private information quality before evaluating the net effect on the information being used in a market.

The model which is closest to our own is Dierker [2006].[6] Dierker's work is motivated by many of the same concerns as ours but differences in the set up of the model add insights. At a simple level, our paper shows which results can be generalized: e.g., where Dierker's work suggests that the amount of information gathered privately is "independent of the level of the cost function" (his Proposition 2) and that the effect of a change in a parameter which measures the returns to scale is ambiguous, our alternative suggests a different conclusion.

At a more complex level, we allow the cost of information to depend on the precision of the disclosure directly. This specification implies that, when analyzing an "optimal" policy, a company's manager cannot pick a cost function; a regulator must consider the many effects of a disclosure for a given type of cost function. Therefore, our numerical simulation can explore the connections amongst different types of traders, under different disclosure settings, more explicitly. We also allow the signals received by different investors to be imperfectly correlated and we highlight the role of the market maker or, more generally, the price mechanism. These features suggest that, for certain values of key parameters, using a zero profit condition as a condition of an equilibrium may produce a puzzle. Because information is a special type of "product" whose value depends on how it can be used, the relationship between the average benefit and the marginal benefit of information in a competitive financial market is atypical: competition between traders differs from the kind of competition seen when car companies or beer companies fight for market share. We show that traders who know that the signals are imperfectly correlated have an incentive to change their individual behavior according to the degree of correlation but that, in the equilibrium which accounts for the interaction between different types of traders, the net effect can be zero. These differences, and using related work on rent-seeking and rent-shifting due to information activities (especially Hirshleifer [1971]), enable us to comment on the social value of information gathering activities.

The remainder of our paper proceeds as follows. The next section develops a model of investors and outlines the information structure. Section 3 characterizes the equilibrium behavior of each type of trader. Section 4 derives the precision of an informed investor's private signal if that signal is endogenous. Section 5 considers the effects of corporate governance

[6] We are indebted to the referee for making us aware of this work.

regulations on various information qualities in capital markets, i.e., public, private and total information, and on various aspects of trading behavior including the expected volume and the market maker's reaction. After deriving closed form solutions for many variables, we use numerical simulations to demonstrate that a policy which changes the required level of disclosure can have unintended perverse consequences. These simulations should help readers to better understand the more subtle aspects of the actions of investors who interact in an information-rich environment. The reactions of the market maker are critical to this interaction. We show that full disclosure tends to benefit liquidity traders and privately informed traders but that the difference in rents earned by liquidity trades does not appear to be closely connected to either the change in trading volume or the change in price informativeness. The second last section offers some conjectures and discusses empirical predictions. The last section provides the concluding remarks, policy implications and suggestions for future research.

2. The Strategic Investor Model

Our model includes four types of risk neutral traders: a firm's manager, a single privately uninformed rational investor, multiple privately informed rational investors (i= 1, …, I), and liquidity traders. The manager and each privately informed investor trades to maximize profits based on their own private information. The liquidity traders (also referred to as noise traders) trade for reasons that are independent of the market price. The number of shares traded by the liquidity traders is exogenously specified as $Z_l \sim \mathrm{N}(0,\sigma_Z^2)$.[7] The privately uninformed investor, also called the market maker, does not observe the individual quantities traded by the manager and the privately informed investors as well as the liquidity traders, but does observe the aggregate quantity. The uninformed investor uses this observation to imperfectly infer the manager's and the informed investors' private information, and sets the market price to ensure that he breaks even in expectation. The presence of noise traders is important since it guarantees that market price does not fully reveal the private information.

[7]As common in Kyle type model, the preferences of liquidity traders are not modeled. While this fact prevents precise analysis of social welfare issues, our simulations use an approximation to offer some crude insights.

Figure 1: **Timeline of the Strategic Investor Model**

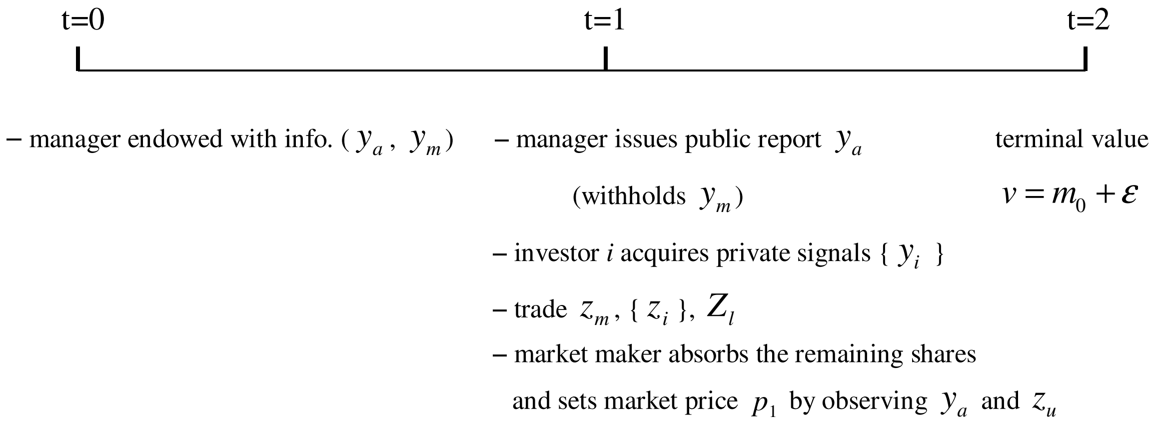

Figure 1 shows the sequence of events and information structure in our model. At date zero, the manager is endowed with some information about the terminal firm value: her signals are (y_a , y_m). At t= 1, the manager discloses y_a to the public, which is observed by all investors, and withholds y_m. Then the multiple privately informed investors acquire costly private signals y_i where i= 1, …, I. Based on their own bits of private information, the manager and informed investors and liquidity traders place orders simultaneously. The market maker, does not know y_m or { y_i }. He observes the aggregate quantity (z_u) but does not directly observe the individual quantities traded by the manager (z_m), by the privately informed investors ({ z_i }) or by the liquidity traders (Z_l). As market maker, he absorbs the remaining shares to clear the market and sets the market price. At t= 2, the firm's terminal value is realized.

Since the manager and informed investors combine their own private information with the public report to determine the trading quantities, the market clearing price depends on both bits of information. As is common in Kyle type models, the manager and informed investors individually anticipate that their choice of demand function influence the other traders and the market price. Instead of acting as a price taker, each has an incentive to restrain their trades in order to partially hide their private information. This feature deserves special note since many regulatory reforms aim to both change the distribution of information and make markets more efficient. These goals are not always compatible.

Information Structure

Since the information-gathering behavior of investors depends on what other traders know, we note how the information used by each type of trader is related to the other traders and to the firm's value. The terminal value of the firm is represented by $v = m_0 + \varepsilon$, where ε is a zero mean, Normally distributed random variable, i.e., $\varepsilon \sim N(0, \sigma_0^2)$. The trades of liquidity traders, Z_l, are not correlated with the other random variables in this model. Further, the prior beliefs with respect to the public report, y_a, and the information withheld by the manager, y_m, are $y_a \sim N(0, \sigma_a^2)$, $y_m \sim N(0, \sigma_m^2)$ and $Cov(y_a, y_m) = 0$. Each informed investor is assumed to receive a private signal y_i which share a common mean: $y_i \sim N(0, \sigma_i^2)$ for i= 1, …, I. The signal received by private investors and any information withheld by the manager are correlated in the sense that both are related to the firm's terminal value but, conditional on that value v, the private signals and the manager's information are independent: i.e., $Cov\ (y_a, y_i) = 0$ and $Cov(y_m, y_i) = 0$. This assumption has the effect of implying that the manager and the informed investors are informed about different components of the noise of the firm value. We will expand on this idea later when we discuss how different types of disclosures affect the precision of the information acquired by informed investors.

The signals of different privately informed investors are correlated in the sense that the signals share a common distribution. When making trading decisions, each informed trader must guess at what other informed traders use as the basis of their trading. The assumption on the joint Normality of the distribution of (y_i, y_j) imply that $Cov(y_i, y_j) = k\sigma_i\sigma_j$, with $0 \le k \le 1$, which implies that $E[y_j \mid y_i] = k(\sigma_j / \sigma_i) y_i$.[8] If k= 1 and $\sigma_j^2 = \sigma_i^2$ then $y_i \equiv y_j$: all informed investors would obtain the same private information and all would know that they share this outlook.

Though different traders may receive different signals in the model, they can all be considered as informative about the firm value. Given the public report, the posterior belief on the noise of the firm value is $\varepsilon \mid y_a \sim N(y_a, \sigma_{a1}^2)$. The private signals held by the manager and

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[8] This presentation is similar to that offered by Kim and Verrecchia [1994]. We note that differences between our model and their model create differences in the effects of a change in diversity.

informed investors are informative about the noise: $\varepsilon | y_a, y_m$ ~N($y_a + y_m, \sigma^2_{m1}$) and $\varepsilon | y_a, y_i$ ~ N($y_a + y_i, \sigma^2_{i1}$). Thus, the specified information structure requires that

$$\sigma_0^2 = \sigma_a^2 + \sigma_{a1}^2 = \sigma_a^2 + \sigma_m^2 + \sigma_{m1}^2 = \sigma_a^2 + \sigma_i^2 + \sigma_{i1}^2. \quad (1)$$

The total uncertainty about the terminal firm value is σ_0 where the uncertainty resolved by the public report y_a, is σ_a^2. The incremental uncertainty that can be resolved by information withheld by the manager y_m is σ_m^2; we assume that the uncertainty about firm value which can be resolved by information within the company, $\sigma_a^2 + \sigma_m^2$, is fixed at σ_T^2. The incremental uncertainty that can be resolved by an informed investor's private signal y_i is σ_i^2, for any one investor. Holding σ_0 constant, we interpret σ_a^2 as a measure of the informativeness (or quality) of the public report with respect to ε. Similarly, σ_m^2 and σ_i^2 measure the informativeness (or quality) of the information withheld by the manager and the private signal acquired by the informed investor, respectively.

There are several ways to think about these differences between different types of informed investors. For example, the manager may have better access to historic information (e.g., financial statements) but the informed investor may invest more resources in forward-looking information. At the same time, different privately informed investors may use different research methodologies which may emphasize different subsets of the available data.

Motivating the Ambiguity in Interaction between the Public Signal and the Cost of Gathering Private Information

The ambiguity of the effect on total quantity and quality of information is not commonly discussed, especially if all information is perceived as coming from a single source. Once we admit that privately informed investors can vary the quality of their information, we need to ask: what are the characteristics of the cost expended to gather such information and convert it into a trading decision? A common position might be that stated by Leuz and Wysocki [2008, p. 6-7]: "more information in the public domain [disclosed by companies] makes it harder and more costly for traders to become privately informed." We offer several different perspectives where the central issue to be explored is the relationship between public information and the costs and benefits of information gathered by a private investor.

The perspective shared by Leuz, Wysocki and others would be extremely sensible if public and private information were interchangeable. For example, if a company disclosed no information then private investors could be expected to gather the information needed to estimate the current revenue, expense and profit of the firm. If the firm released precise information about revenue, expense, and profit then information advantage of these investors over other traders would almost disappear. The full impact of the change on trading activity would vary with the investors' confidence that the disclosed information is precise and accurate. To the extent that this example of interchangeability dominates, having a company disclose precise information reduces wasteful duplication of effort and may prevent a costly race for imprecise foreknowledge.

Other examples can be used to motivate different relationships. Each of the following examples starts by noting a reason why publicly-disclosed information and privately-acquired information are not interchangeable in an investor's decision process. The first two note the differences between different kinds of research activities. The last several examples use a looser interpretation of the model, including the idea that investors may want to look for information that the managers want hidden.

Chen, Cheng, and Lo [2010] investigate the information content of what investment analysts publish and note that it could be divided into two categories. Information published before an earnings announcement tends to report discoveries used to forecast earnings while information published after an announcement tends to interpret the information which was disclosed. In this context, the strongest intuition related to our work is that disclosure tends to affect costs by affecting the interpretation of a financial statement after it is released, while the cost of discovery-type research tends to be independent of the precision of any specific disclosure.

The process of gathering information privately about something which is disclosed may have a useful by-product because an investor who relies on the disclosure for information about the company's cost and revenue would be less aware of details which, upon further investigation, could improve their trading profits. More generally, to prepare a report which offers non-trivial insights based on recently disclosed data and to publish it quickly, an analyst needs to organize background information in case it is needed. The effect of this activity on cost is ambiguous.

When more types of information are disclosed, if not necessarily more precise information, an analyst needs to prepare more background information in case it is needed and can suffer from disclosure overload. On the other hand, certain kinds of disclosures can reduce the costs incurred later by indicating that certain situations are so unlikely that they are not worth investigating: a common example would occur when a firm offers an "earnings warning" which makes investors aware of certain concerns without offering a precise fact or prediction of the ultimate effect of that concern.

Anticipating a more precise disclosure may lead some analysts to reallocate their efforts toward interpretative activities. Voluntary reallocation usually suggests that the total cost would fall, since an investor would prefer to substitute toward a lower cost source of information if allowed, but the different sources do not lead to an identical decision because public disclosure also changes the relationship amongst the informed investors, market maker and the liquidity traders. Thus, the net effect cannot be summarized easily by a change in total cost.

Specific disclosures in the notes to financial statements or the Management Disclosure and Analysis (MD& A) reveal information and knowing this information can encourage investors to look for other information: e.g., a firm which discloses the potential effects of various risk factors (such as the effects on earnings of an increase in interest rates, oil prices or foreign exchange rates) can enable an investor to profit by forecasting interest rates or oil prices or conditions in another country, even if the forecast is costly. This kind of research is especially relevant to the kinds of forward-looking research demanded by many investors.

Sometimes, information may have no direct value either in terms of enabling investors to infer the future value of a firm or in terms of the risks associated with the investment; sometimes, the insight from a bit of information depends on matching *two* bits of information. For example, disclosing that a firm will enter one of two geographically distinct markets has ambiguous implications if the firm has a competitor which is also thinking of entering one of the two markets, especially if both markets are only large enough to support one producer. If one firm chooses to go into market A and if the other firm has chosen to enter market B, then both would profit. If both firms choose to go into the same market, then both would lose money. Therefore, the simple disclosure that the firm will enter a market, without more information, has limited significance. But, without that disclosure, a private investor would have no incentive to gather the complementary information.[9]

If we allow for a slightly looser interpretation of the notation, some other reasons become reasonable. First, some papers (e.g., McNichols and Trueman [1994]) studying the effects of disclosure assume that the disclosure concerns a scalar variable which is a sufficient "summary statistic". While the resulting model is logically valid, and this assumption enables them to study interesting questions, one can argue that disclosing information in a disaggregated form may reveal more insight than is possible if the information were presented in an aggregated form. In an aggregate form, private investors are limited in the kinds of questions they can ask but if information is disaggregated then each segment can be investigated separately. And, as people who suffer from information overload understand, the additional dimensions cannot be ignored entirely. With increasing marginal cost to the research activity, a disclosure which forces an informed investor to research more aspects *increases* their total cost. Caskey [2008] and Beyer et al. [2010] offer longer discussions of the costs and benefits of disclosing information at different levels of aggregation.

Our cost function may also represent the effects of competition amongst investors. If information gathering activities are designed to interpret the meaning of the public information, and especially if all interpret the same information sources in the same way (i.e., $k= 1$), then all informed investors would reach the same conclusion eventually but someone could reach that conclusion faster by investing more resources: essentially, informed investors seek foreknowledge but they may be in a Prisoner's Dilemma situation where the benefits of being first vary with the disclosure regime. Beyer et al. [2010] review some of the research on competition between stock market analysts in terms of "timeliness" as opposed to the precision of the analysis. Disclosing more precise information may increase the speed of this race but, in the end, produces no change in the relative rank order of investors and, therefore, no change in total trading profits. Our model recognizes some of these effects although its representation of the time dimension is limited.

Even without the profit motive to encourage investors to acquire information, there is social value in having private investors collect information on their own to verify a public report

[9] We do not consider whether disclosing information is competitively neutral. In a competitive model, one company's decision to disclose information may alter its value by inducing a change in the marketing or production strategy of a competitor and a company's competitive position can influence its decision of how much and what to disclose to other stakeholders. Discussing these issues is beyond the scope of this paper: see Wagenhofer [1990] or Beyer et al. [2010, esp. p. 327] for more insights.

(Dong and Lin [2010]), to explore alternatives or to investigate rumors of fraud.[10,11] An increase in mandated disclosure may cause investors to become careless in their fact-checking or it may enable investors to cross-check the added disclosures with other bits of information, depending on which information is released. Disclosure regulation might increase the cost to the manager of hiding fraud but more disclosure and more precise disclosure by a firm which wants to deceive investors should also raise the cost of private research: information overload makes it harder for a determined researcher to identify which bit of information is a "smoking gun" that reveals a fraud. Therefore, it is possible for an increase in the apparent precision of a disclosure to increase the real cost of producing profitable private information. Even if the information gathered by an investor were an exact copy of what might be disclosed, the fact that the investor gathered the data independently enhances its credibility to that investor, affects their trading activity and, perhaps, makes the financial system less fragile.

Beyer et al. [2010, p. 303] add to this intuition with their discussion of the "unraveling result". This result implies that companies would want to disclose a lot voluntarily and Beyer et al. [2010] note that the formal argument which supports the "unraveling result" depends on all disclosures being truthful and that investors know that the manager has some private information. Equivalent conditions may exist in a less restrictive formal model if investors can gather the kinds of information which enable them to ask tough questions of a manager who tries to hide relevant information.

For all of these reasons, we allow for the various possibilities that an increase in disclosure may increase the private cost of acquiring information or may decrease its cost or may have no effect.

[10] Looking for disconfirming evidence may become especially costly when the search must access unusual sources of information and unusual ways of thinking. Yet, as demonstrated by the consequences of the SEC's repeated failure to act on complaints about B. Madoff, the existence of disconfirming evidence can be especially important in a larger sense.
Beyer et al. [2010, p. 327] notes an additional effect: that bad news may be conveyed more credibly in ways that good news cannot. Our model does not consider this asymmetry since investors use trading rules which are linear functions of the signal and linearity is sensible given the assumptions of the model.

[11] Although not the focus of our model, financial disclosures can also be useful to people outside of the investment community: e.g., employee groups may combine the information disclosed with other sources of information when negotiating job contracts or special interest groups may comment on corporate disclosures using their own sources of information.

3. *Characterization of Market Equilibrium and Information Quality*

The following discussion introduces and motivates the notation. The more technical aspects of finding the equilibrium solution are contained in the Appendix. Initially, we treat σ_i^2 as exogenous, and defer the detailed consideration of the informed investor's decision on private signal acquisition to the next section. z_m and z_i represent the orders placed by the manager and an informed investor, respectively. The orders placed by the liquidity trader are summarized by Z_l. Hence, the aggregate quantity traded by the three sets of traders is

$$z_u = Z_l - (z_m + \sum_{i=1}^{I} z_i) . \tag{2}$$

The uninformed investor observes the aggregate quantity z_u but does not observe the quantities traded by each type of individual. Based on this observation, he acquires those shares to clear the market, and sets a market price, denoted as p_1. The trading profits for the manager, informed and uninformed investors are

$$\pi_m = (v - p_1) z_m,$$

$$\pi_i = (v - p_1) z_i,$$

$$\pi_u = (v - p_1) z_u. \tag{3}$$

where we temporarily ignore the information acquisition costs and temporarily treat the degree of informativeness as exogenous.

In equilibrium, the best that an uninformed investor can expect to do is to break even. Thus, the market price, p_1, equals the expected terminal value of the firm based on the information available to the uniformed investor: the public report y_a, and the aggregate quantity z_u:

$$p_1 = E_{u1}[v \mid y_a, z_u] = m_0 + y_a + \mu_{u1}(z_u). \tag{4}$$

where $\mu_{u1}(z_u) = E[\varepsilon_{av} \mid z_u]$, and $\varepsilon_{av} = \varepsilon - y_a$ represents the prior belief about the noise in the public report. The term $\mu_{u1}(z_u)$ is the uninformed investor's posterior mean with respect to ε_{av} conditional on z_u.

The manager and the informed investors conjecture that the posterior mean is proportional to the aggregate quantity:

$$\mu_{u1}(z_u) = E[\varepsilon_{av} \mid z_u] = -bz_u . \tag{5}$$

At the same time and based on their private information, the manager and each informed investor conjectures what others will demand. The conjectured demands are

$$z_m = \alpha y_m ,$$

$$z_i = \beta y_i \ . \tag{6}$$

Given these conjectures, informed investor *i* expects the price resulting from an order of z_i units, given his signals (y_a, y_i), to be

$$E[p_1 \mid y_a, y_i, z_i] = m_0 + y_a + bz_i + b\beta \sum_{j \neq i} E[y_j \mid y_i] . \tag{7}$$

The assumption of symmetric informed traders implies that each informed trader conjectures that all other informed traders use the same type of trading rule in equilibrium. Joint Normality implies that the anticipated differences in the private information can be described by

$$E[y_j \mid y_i] = k(\hat{\sigma}_j / \sigma_i) y_i \ . \tag{8}$$

for all *i* and *j* ($0 \le k \le 1$) where $\hat{\sigma}_j^2$ refers to trader *i*'s conjecture about the information gathered by other informed traders. To find a symmetric equilibrium, we assume that all traders but trader *i* make the same decision and that trader *i* uses this assumption when deciding whether or not to deviate from a possible equilibrium. Informed investor *i*'s trading profit can be calculated as $\pi_i = (v - p_1) z_i$ and, using equations (6), (7) and (8), his expected trading profit conditional on his signals (y_a, y_i) is

$$U_{i1}(y_a, y_i, z_i) = \{ y_i - b\beta y_i \sum_{j \neq i} k(\hat{\sigma}_j / \sigma_i) - bz_i \} z_i . \tag{9}$$

An informed investor maximizes this expression by choosing

$$z_i(y_i) = [1 - b\beta \sum_{j \neq i} k(\hat{\sigma}_j / \sigma_i)] y_i / (2b) . \tag{10}$$

The manager and the uninformed investor also make conjectures about the actions of other traders and use them when making trading decisions. In a symmetric rational expectations equilibrium, these conjectures are consistent with the optimal choice of each actor. The following lemma characterizes the behavior of the different actors in a market equilibrium.

Lemma 1

In the strategic investor model with limited disclosure, the equilibrium demands of different types of trader and the market price are characterized by $\alpha = \frac{1}{2b}$, $\beta = \frac{1}{(2+(I-1)k)b}$,

$p_1 = m_0 + y_a - bz_u$, where $b^2 = [\frac{1}{4}\sigma_m^2 + \frac{I}{(2+(I-1)k)^2}\sigma_i^2]\frac{1}{\sigma_Z^2}$ with $\sigma_m^2 = \sigma_T^2 - \sigma_a^2$.

Proof: see the Appendix.

Properties of the Equilibrium:

The demand functions for the manager and the informed investors have a similar structure but differ because they are based on different bits of information. Simple comparative static analyses indicate that the orders placed by the manager and informed investors are increasing in the liquidity noise σ_Z^2, while each is decreasing in the precision of their private signal σ_m^2 and σ_i^2. Since the market maker infers the private signals imperfectly, anything which reduces the ability of the market maker to infer the details of those private signals implies that the manager and informed investors are less constrained and that they can earn more profit.

Substituting the solutions for α, β and the equilibrium price expression found in Lemma 1 implies that

$$p_1 = m_0 + y_a + \frac{1}{2}y_m + \frac{1}{2+(I-1)k}\sum_{i=1}^{I} y_i - bZ_l\,. \tag{11}$$

The "correct" price, p_1^*, is that which would be set by the market if all information were publicly disclosed. In this model, that price would be

$$p_1^* = E[v \mid y_a, y_m, \{y_i\}] = m_0 + y_a + y_m + \frac{1}{1+(I-1)k}\sum_{i=1}^{I} y_i \tag{12}$$

which represents the informed posterior mean. We define a price-informativeness measure as the covariance between the informed posterior mean and the price, referred to as the total information quality.[12]

Proposition 1

In the strategic investor model with limited disclosure, the total information quality incorporated into the equilibrium market price is

$$\Phi \equiv Cov(p_1^*, p_1) = \sigma_a^2 + \frac{1}{2}\sigma_m^2 + \frac{I}{2+(I-1)k}\sigma_i^2 .$$

Proof: see the Appendix.

This proposition implies that the equilibrium market price reflects the publicly disclosed information fully and the hidden signals only partially. Competition between investors implies that the information gathered by informed investors becomes fully revealed in the price, as the number of informed investors tends to infinity, if and only if $k = 1$.

4. *Endogenous Quality of the Private Signals*

The previous sections treated the precision of the informed investors' private signal as exogenous. This section considers the decision of private investors to acquire information and, in particular, considers the costs and benefits of obtaining more precise information.

We suppose that the cost of acquiring information is the same for each informed investor, and that it is represented by the following function form:

$$\kappa_i(\sigma_a^2, \sigma_i^2) = \exp(\gamma\sigma_a^2)(\sigma_i^2 + c(\sigma_i^2)^2) . \tag{13}$$

where $c \geq 0$. This cost function displays a couple of useful characteristics. First, it should be familiar since it mimics the kinds of cost function (of output) used in managerial accounting: there is no cost when no information is gathered and, for a given σ_a^2, variable cost increases with σ_i^2 (at an increasing rate if c> 0). Second, the cost function is separable in σ_a^2 and σ_i^2, which simplifies the algebraic analysis. Separability also implies that we can note that the effect on an investor's cost unambiguously (i.e., without qualifying the discussion by mentioning the level of

[12] Grossman and Stiglitz [1980] define a price-informativeness as the squared correlation between the informed posterior mean and the price.

σ_i^2).[13] Third, $\exp(\gamma\sigma_a^2) > 0$ for all σ_a^2 and γ, regardless of whether this private information cost parameter γ is positive, negative or zero. This feature makes the exp(.) function a popular choice in some types of empirical analysis (e.g., Greene [1990, section 14.11], Cameron and Trivedi [2005, section 5.9.2]). Where previous researchers have used similar cost functions to explore cases analogous to $\gamma = 0$ (e.g., Kim and Verrecchia [1991], McNichols and Trueman [1994]), this functional form emphasizes the idea that an increase in public information quality decreases (or increases) the information cost when $\gamma < 0$ (or $\gamma > 0$). An increase in $\exp(\gamma\sigma_a^2)$ increases the total cost of gathering and increases the marginal cost; this statement is true regardless of whether γ or σ_a^2 increases but an increase in σ_a^2 does not necessarily increase costs.

Formally, a disclosure which reveals everything known to the company does not necessarily reveal the value of the company perfectly: we assume that there is a fixed upper bound on the total information which could be disclosed, $\sigma_a^2 + \sigma_m^2$. Call that upper bound σ_T^2 and, since this substitution would have unnecessarily complicated previous derivations if it had been made earlier, we replace σ_m^2 by $\sigma_T^2 - \sigma_a^2$ wherever appropriate.

Even if publicly disclosed information is interchangeable with privately acquired information, the effect on trading behavior of a disclosure regulation is not mechanical; it must account for the relationship between public and private information and the changing relationship between different types of traders. Each individual combines their choice of trading rule and of information gathering activity for their own benefit. In a symmetric equilibrium, $z_i = \beta y_i$, $z_j = \beta y_j$ and $\sigma_i^2 = \sigma_j^2 = \hat{\sigma}_j^2$ for all informed investors *i* and *j* but, to characterize that equilibrium, we need to allow for the possibility that investor *i*'s choice for σ_i^2 can differ from what investor *i* anticipates about other investors (i.e., $\hat{\sigma}_j^2$). Equation (10) recognizes that perspective and the proof of the following lemma uses it to characterize the equilibrium solution.[14]

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[13] Our specification of the cost function does not include a parameter which independently raises or lowers the overall function directly. Since Dierker [2006] considers the effects of such proportional shifts in the cost function, we have nothing to add on this point.

[14] Since we wish to focus on the links between disclosure and total information quality, our analysis focuses on the more interesting case in which not all traders act as liquidity traders: i.e., some private information is collected. This

Lemma 2

In the equilibrium to the strategic investor model with limited disclosure and fixed *I*, informed investor *i*'s choice of private signal quality is characterized by

$$\exp(\gamma\sigma_a^2)(1+2c\sigma_i^{2*}) = \frac{1}{2(2+(I-1)k)}\frac{\sigma_Z}{\sqrt{\frac{1}{4}(\sigma_T^2-\sigma_a^2)+\frac{I}{(2+(I-1)k))^2}\sigma_i^{2*}}}$$

The informed investor *i*'s *ex ante* expected net payoff is

$$U_i^{net}(\sigma_i^{*2}) = \frac{1}{(2+(I-1)k)^2}\frac{\sigma_Z\sigma_i^{*2}}{\sqrt{\frac{1}{4}(\sigma_T^2-\sigma_a^2)+\frac{I}{(2+(I-1)k))^2}\sigma_i^{*2}}} - \kappa_i(\sigma_a^2,\sigma_i^{*2})$$

Corollary 1

(i) If $\gamma = 0$, then an increase in σ_a^2 increases σ_i^{2*}.

(ii) $\gamma < 0$ is a sufficient, but not necessary, condition for an increase in σ_a^2 to increase σ_i^{2*}.

(iii) An increase in *I* decreases σ_i^{2*}.

(iv) An increase in *k* decreases σ_i^{2*} if *I*> 1.

Proof: see the Appendix for the proofs.

Part (i) of the Corollary shows the effect, in the case of no interaction effect on the cost of gathering information (i.e., $\gamma = 0$), of an increase in the disclosed information which reduces the information restricted to the managers: the increase in σ_a^2 increases σ_i^{2*} because it decreases the market maker's choice of *b*. If $\gamma \neq 0$ then an increase in σ_a^2 has a second effect on an investor's cost of information which may oppose the first effect.

Parts (iii) and (iv) identify the effect of a change in the number of traders or the diversity of information (i.e., *k*). Under the equilibrium conditions, the marginal cost of information is equal to the marginal benefit due to trading profit plus the marginal benefit due to foreknowledge (i.e., knowing relatively more than the other informed traders). An increase in *I* or an increase in

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outcome is not guaranteed to be true in the equilibrium because the marginal benefit of information to an informed trader can be less than the marginal cost. More formally, $\sigma_i^{2*} > 0$ if $\sigma_Z / \left((2+(I-1)k)\sqrt{(\sigma_T^2-\sigma_a^2)}\right) > \exp(\gamma\sigma_a^2)$.

k affects the degree of competition between traders but it also affects the personal benefit associated with foreknowledge. The equilibrium solution presented in Lemma 2 accounts for both effects.

5. The Effects of Disclosure

Accounting scandals and self-dealing by corporate insiders shook investor confidence in the integrity of securities markets during the early 2000s. Concerns about "toxic assets" and the unforeseen implications of counter-party risk shook investor confidence during the credit crunch of 2007-2008 and led many investors to wonder whether the experts knew what they were doing. Politicians seem to acknowledge the idea that financial markets process a lot of information and many recent proposals aim to uncover information about problems before those problems destabilize a company or the financial system. For example, the Sarbanes-Oxley Act was intended to improve the direct oversight by a board of directors, the accountability of managers and to improve the indirect oversight by way of financial market forces.

The previous discussion focused on a model of a firm with a fixed set of information and a manager who discloses some information and withholds some information. This section considers a setting with the same fixed set of information and a manager who is required to disclose all of that information publicly. Thus, the public information observed by all investors increases from one signal y_a to two signals (y_a , y_m) and the total informativeness of the public signals increases to $\sigma_a^2 + \sigma_m^2 \equiv \sigma_T^2$. Hence, the cost function for gathering private information becomes

$$\kappa_i^{'}(\sigma_a^2, \sigma_m^2, [\sigma_i^{'}]^2) = \exp(\gamma(\sigma_a^2 + \sigma_m^2))([\sigma_i^{'}]^2 + c([\sigma_i^{'}]^2)^2)\,. \tag{14}$$

Based on an argument similar to that used in Lemma 1, Lemma 3 describes the behavior of market participants in equilibrium.

Lemma 3

In the strategic investor model with full disclosure, the market equilibrium satisfies

(a) informed investor *i*'s demand: $z_i^{'}(y_i) = \beta^{'} y_i = \frac{1}{\sqrt{I}} \frac{\sigma_Z}{\sigma_i^{'}} y_i\,.$

(b) the market price: $p_1^{'} = m_0 + y_a + y_m - b^{'} z_u^{'}$, where $b^{'} = \frac{\sqrt{I}}{2+(I-1)k} \frac{\sigma_i^{'}}{\sigma_Z}$.

Proof: see the Appendix.

Lemma 3 implies that the informed investors trade more aggressively if there is more liquidity noise and that, as the number of informed investors increases, competition between them leads each individual to trade less for a given signal. What may be surprising about this result is that the equilibrium demand of an investor does not vary with *k* conditional on σ_i^2.

Substituting $b^{'}$ into the equilibrium price expression in Lemma 3 yields

$$p_1^{'} = m_0 + y_a + y_m + \frac{1}{(2+(I-1)k)} \sum_{i=1}^{I} y_i - \frac{\sqrt{I}}{2+(I-1)k} \frac{\sigma_i^{'}}{\sigma_Z} Z_l \qquad (15)$$

Proposition 2

In the strategic investor model with full disclosure, the equilibrium total information quality incorporated in the market price is

$$\Phi^{'} \equiv Cov(p_1^{*}, p_1^{'}) = \sigma_a^2 + \sigma_m^2 + \frac{I}{2+(I-1)k}[\sigma_i^{'}]^2 .$$

Proof: see the Appendix.

Compared with the limited disclosure setting, the price now captures y_m fully. The fraction of private information captured by the market price does not change from the previous setting but the amount of information gathered privately may increase or decrease. Using the same steps as used when deriving the equilibrium for limited disclosure, but accounting for a change in the behavior of different types of investors, we can characterize the equilibrium level of information chosen by an informed investor.

Lemma 4

In the strategic investor model with full disclosure, the equilibrium level of informed investor *i*'s private signal quality, $\sigma_i^{'}$, is characterized by

$$\exp(\gamma(\sigma_a^2+\sigma_m^2))(1+2c[\sigma_i^{'*}]^2)=\frac{\sigma_Z/\sigma_i^{'*}}{2\sqrt{I}}.$$

The informed investor *i*'s *ex ante* expected net payoff in equilibrium is:

$$U_i^{net'}(\sigma_i^{'*})=\frac{1}{(2+(I-1)k)}\frac{1}{\sqrt{I}}\sigma_Z\sigma_i^{'*}-\exp(\gamma(\sigma_a^2+\sigma_m^2))([\sigma_i^{'*}]^2+c([\sigma_i^{'*}]^2)^2)$$

Proof: see the Appendix.

Comparative statics analysis demonstrates that an increase in the informativeness of public information, $\sigma_a^2+\sigma_m^2$, increases (decreases, does not affect) the equilibrium precision of the private signal $\sigma_i^{'*}$ if $\gamma<0$ ($\gamma>0$, $\gamma=0$). This result differs from the case of limited disclosure where the difference in the settings affects the behavior of the market maker. Informativeness does not vary with *k* in this setting. Corollary 2 shows that, regardless of the direction of the effect, the magnitude varies with the relative importance of liquidity traders vs. informed traders: i.e., $\sigma_z/\sqrt{I}$.

Corollary 2

With full disclosure, an increase in $\sigma_z/\sqrt{I}$ reduces $\partial[\sigma_i^{'*}]^2/\partial(\sigma_a^2+\sigma_m^2)$ toward 0. In other words, an increase in $\sigma_z/\sqrt{I}$ decreases $\partial[\sigma_i^{'*}]^2/\partial(\sigma_a^2+\sigma_m^2)$ if $\partial[\sigma_i^{'*}]^2/\partial(\sigma_a^2+\sigma_m^2)>0$ and an increase in $\sigma_z/\sqrt{I}$ increases $\partial[\sigma_i^{'*}]^2/\partial(\sigma_a^2+\sigma_m^2)$ if $\partial[\sigma_i^{'*}]^2/\partial(\sigma_a^2+\sigma_m^2)<0$.

Proof: see the Appendix.

Comparing the Information Quality in Two Settings

This section compares the equilibrium information qualities in a setting with limited disclosure vs. that with full disclosure. In our model, the regulation requires full disclosure and the manager has no private information. Consequently, the regulations both increase the informativeness of public disclosure from σ_a^2 to $(\sigma_a^2+\sigma_m^2)$ and limit an insider's information advantage.

Comparing Propositions 1 and 2 shows that the change in total information quality is

$$\Delta_\Phi\equiv\Phi^{'}-\Phi=\frac{1}{2}\sigma_m^2+\frac{I}{2+(I-1)k}\{[\sigma_i^{'*}]^2-\sigma_i^{*2}\}\qquad(16)$$

where Lemma 2 shows that the precision of the private signal in the limited disclosure setting is characterized by

$$\exp(\gamma\sigma_a^2)(1+2c\sigma_i^{2*}) = \frac{1}{2(2+(I-1)k)}\frac{\sigma_Z}{\sqrt{\frac{1}{4}(\sigma_T^2-\sigma_a^2)+\frac{I}{(2+(I-1)k))^2}\sigma_i^{2*}}}$$

and Lemma 4 shows that its precision in the full disclosure setting is characterized by

$$\exp(\gamma(\sigma_a^2+\sigma_m^2))(1+2c[\sigma_i^{'*}]^2) = \frac{\sigma_Z/\sigma_i^{'*}}{2\sqrt{I}}.$$

Common intuition suggests that the direct effect of an increase in public information quality would be to increase total information quality. The more subtle effects depend on the equilibrium interaction since the initial intuition does not account for the behavior of investors who may study other information sources more or less intensively. Therefore, an increase in the level of public information quality can be offset by a decrease in the level of private information quality.

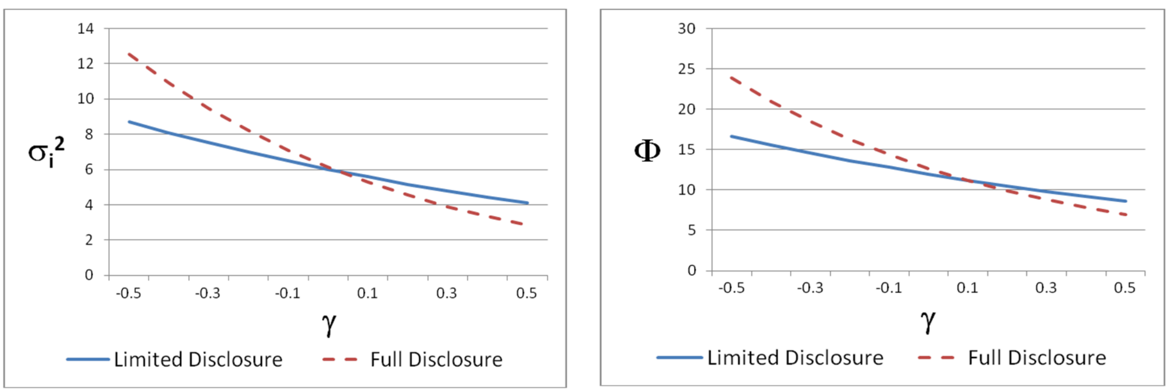
We illustrate this ambiguity with numerical examples. Table 1 and Figure 2 show that an increase in the information cost parameter γ decreases the private signal precision under both settings and that, more importantly for policy purposes, the effect of disclosure is less when γ is greater. In this example, the other parameters are σ_Z^2= 5000, I = 4, k= 0.1, c= 0.5 σ_a^2= 1, σ_m^2= 1 and σ_T^2= 2. If γ were equal to 0.0, then full disclosure would lead private investors to increase the quality of the information they acquire, and hence increase the quality of total information. An increase in γ would lead to a lower quality of private information and, if γ= 0.2, this indirect effect becomes large enough to decrease total information quality. The specification of equations (13) and (14) imply that an increase in γ has a proportional effect on the cost of information for any individual but Figure 2 illustrates that the effects on the equilibrium are not equal in the two regimes. In sum, the net effect of enhanced governance on information efficiency and price accuracy varies from industry to industry according to the type of private information and its relationship to the information sought by informed investors.

Table 1: Equilibrium Information Quality

	Limited Disclosure		Full Disclosure	
γ	σ_i^{2*}	Φ	$[\sigma_i^{\prime *}]^2$	Φ'
-0.5	8.70	16.63	12.56	23.84
-0.4	8.09	15.57	10.91	20.98
-0.3	7.52	14.57	9.47	18.47
-0.2	6.98	13.65	8.21	16.27
-0.1	6.48	12.78	7.10	14.35
0.0	6.02	11.96	6.14	12.67
0.1	5.58	11.20	5.29	11.20
0.2	5.17	10.49	4.55	9.92
0.3	4.79	9.83	3.91	8.80
0.4	4.43	9.21	3.34	7.82
0.5	4.10	8.62	2.85	6.96

This table shows the effects of varying the information cost parameter γ on the equilibrium. In this example, the other parameters are σ_Z^2 = 5000, I = 4, k= 0.1, c= 0.5, σ_a^2 = 1, σ_m^2 = 1 and σ_T^2 = 2.

Figure 2: Effect of Disclosure on Private and Total Information Quality



This figure shows the equilibrium values of total information quality and of private information while varying the information cost parameter γ. In this example, the other parameters are σ_Z^2 = 5000, I = 4, k= 0.1, c= 0.5, σ_a^2 = 1.0, σ_m^2 = 1.0 and σ_T^2 = 2.0.

We suggest that a critical feature of this example is that σ_i^2 needs to be large in some sense, especially when compared to $\sigma_m^2 = 1$. If σ_i^2 were small, and especially since competition between traders ensures that a significant fraction of privately gathered information is already included in total information quality, then the impact of most changes in market conditions on private information would be small; thus, any impact on total information quality would be limited. Computation demonstrates that the breakeven point, showing when disclosure has the same effect on total information quality, occurs at γ=0.09991. Private information quality is equal in both settings at γ=0.02729. (If γ=0.1 then the implied shift of the information gathering cost function is exp(0.1 (1+ 1))/ exp(0.1 (1)) - 1= 0.105 or about 10 percent.) Our numerical analysis indicates that σ_i^2 can vary and it is interesting to suggest that recent changes in information technology (such as those listed in the Introduction) may be sufficiently large as to change the preferred policy.

Implications for Trading Volume

Since the critical insights from this equilibrium model arise due to changes in the interaction between traders, especially the market maker, it is interesting to explore the effects of disclosure on expected trading volume. Some simple expressions enable us to discuss these implications.

When managers trade and do not disclose all information, trading volume is

$$V = \frac{1}{2}(| Z_l | + | z_m | + \sum_{i=1}^{I} | z_i |) . \tag{17}$$

As shown by Kim and Verrecchia [1994], the expected trading volume *E[V]* can be expressed simply if the random variables are described by the Normal distribution: if $x \sim \mathrm{N}(0, \sigma^2)$ then $E[| x |] = \sigma\sqrt{2/\pi}$. Therefore, given our equilibrium, the expected trading volume in the limited disclosure setting is

$$E[V] = (\sigma_Z + \alpha\sigma_m + I\beta\sigma_i^*) / \sqrt{2\pi} . \tag{18}$$

A similar argument shows that the expected trading volume in the full disclosure setting, when the manager is not an active trader, is

$$V^{'} = \frac{1}{2}(| Z_l | + \sum_{i=1}^{I} | z_i |) \text{, and } E[V^{'}] = (\sigma_Z + I\beta^{'}\sigma_i^{'*}) / \sqrt{2\pi} \tag{19}$$

The values of α, β, b, $\beta^{'}$ and $b^{'}$ which are appropriate for each setting can be found in Lemmas 1 and 3.

The net effect on expected trading volume depends on whether $\beta^{'}\sigma_i^{'*}$ is sufficiently greater than $\beta\sigma_i^*$ to offset any reduction in trading based on information withheld by management.[15] Our simple example in Table 2 indicates that disclosure may increase total information quality while increasing expected trading volume (e.g., γ= 0.0). In other cases (e.g., γ= 0.2), disclosure decreases total information quality while increasing expected trading volume.

Table 2: Effects of a Change in Other Exogenous Parameters

Exogenous Parameters					Limited Disclosure			Full Disclosure		
γ	I	k	σ_m^2	c	σ_i^{2*}	Trading Volume	Φ	$[\sigma_i^{'*}]^2$	Trading Volume	$\Phi^{'}$
-0.2					6.98	69.04	13.65	8.21	84.63	16.27
0.0	4	0.1	1.0	0.50	6.02	69.28	11.96	6.14	84.63	12.67
0.2					5.17	69.54	10.49	4.55	84.63	9.92
	2				7.70	60.40	8.84	7.90	68.10	9.52
	4				6.02	69.28	11.96	6.14	84.63	12.67
	8				4.66	80.10	15.30	4.74	108.00	16.05
		0.0			6.05	71.71	13.59	6.14	84.63	14.27
		0.1			6.02	69.28	11.96	6.14	84.63	12.67
		0.2			5.98	67.32	10.71	6.14	84.63	11.44
			0.5		6.08	68.24	11.82	6.14	84.63	12.17
			1.0		6.02	69.28	11.96	6.14	84.63	12.67
			2.0		5.90	70.62	12.26	6.14	84.63	13.67
				0.25	9.36	68.60	17.78	9.48	84.63	18.49
				0.50	6.02	69.28	11.96	6.14	84.63	12.67
				1.00	3.83	70.10	8.16	3.95	84.63	8.87

This table shows the effects of change in γ, I, k, σ_m^2 and c where the other parameters are σ_Z^2 = 5000 and σ_a^2 = 1.0, and $\sigma_T^2 = \sigma_a^2 + \sigma_m^2$. The benchmark values used for the exogenous variables are reported in the second row of numbers. The remaining entries report only selected values in order to emphasize the parameter which differs from that benchmark. Interested readers are directed to the Appendix which contains a supplementary table showing the values of the other endogenous variables which, together, determine the equilibrium.

This table shows that the effect of an increase in γ on trading volume for a given setting is relatively minor, especially when compared with the significant effect on σ_i^{2*} or when compared to the effect of changes in other parameters such as the number of traders. An increase in the diversity of private signals, i.e., a decrease in k, increases trading volume and total

[15] Even if senior executives do not trade actively, the market maker needs to anticipate that it is possible for them to trade or, in some countries, that a friend of the manager will trade based on receiving a "hot tip". Indjejikian, Lu and Yang [2011] discuss the phenomenon of "information leakage" and "expert networks" which have a similar effect. It is also possible that more junior employees or suppliers may have limited access to a subset of the insider's information and to use such information for trading purposes. Future research may want to consider how disclosure regulation would interact with insider trading regulations.

information quality in the limited disclosure setting.[16] In the full disclosure setting, only a change in *I* affects trading volume because a change in other variables has many effects which, as shown in the algebra, offset each other in the equilibrium to our model. In other cases, the fact that the uninformed trader always makes zero profits in equilibrium means that the market maker adjusts the price according to the equilibrium level of private information without changing the expected level of trading.

These examples raise questions about a conventional wisdom which argues that fuller disclosure enables more people to make informed trading decisions, and makes the market price more informative *because* the market is made more liquid: Leuz and Wysocki [2008, p. 27] note that "Survey evidence suggests that managers believe that such a liquidity benefit [for voluntary disclosures] exists" but Leuz and Wysocki also note that there is little evidence of the magnitude of the benefit. Our model suggests that disclosure alters the interaction between different types of traders in ways that require an understanding of the equilibrium, especially in terms of what different types of traders anticipate about the actions of other traders.

Implications for the Distribution of Rents and Profits

Table 3 shows how changes in the disclosure setting translate into profits or losses for a single privately informed trader and into a benefit or cost for liquidity traders. We ignore other types of traders because the uninformed trader expects to earn zero profit as a condition of the equilibrium and the effect on the manager's profit is directly affected by the regulation and, therefore, relatively obvious. Lemma 2 and Lemma 4 show the profit earned by a privately informed trader under different disclosure setting. Until now, the profits or losses of the liquidity traders have not been relevant; an Appendix shows that the difference in rents accruing to liquidity traders created by fuller disclosure are estimated to be

$$DR = -(b^{'} - b)\sigma_Z^2 . \tag{20}$$

The organization of Table 3 parallels that of Table 2. In general, disclosure increases the net expected profit of an informed trader even after they spend more on information. An

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[16] As a technical detail, we note that any disclosure has an indirect effect of increasing the *unconditional* correlation of the signals of different privately informed traders even if *k* is fixed. Our model supposes that privately informed investors gather information about different components of the noise of the firm value than what the firm could disclose and *k* measures the correlation between the components conditional on the disclosure. If all investors observe a disclosure then that disclosure increases the component of the information about the firm that is common to all investors. This difference may be relevant for empirical research.

increase in the number of informed investors or a reduction in the diversity of their information reduces the expected profit of each in either setting.[17] This table also shows how the incentives for individual traders can lead to counter-intuitive outcomes because the equilibrium effects of an increase in the cost function vary with the disclosure setting. Any one trader would be worse off if their cost increased but all can benefit from a joint increase in the cost function because part of the incentive to gather information, as is evident when computing the first order condition used to solve for σ_i^{2*}, is to gather relatively more information than other traders in a race to be first ("foreknowledge"). If all investors gather less information then, after accounting for the reaction of the market maker to the change in context and the change in information collected by other informed investors, an investor may be better off or worse off in equilibrium.

Table 3: Net Profit earned by an Informed Trader and Difference in Rents to Liquidity Traders

Exogenous Variables					Limited Disclosure		Full Disclosure		Liquidity Traders	
γ	I	k	σ_m^2	c	Net Profit	Info. Cost	Net Profit	Info. Cost	DR	Δ_Φ
-0.2					0.83	25.68	15.96	28.07	72.81	2.63
0.0	4	0.1	1.0	0.50	0.45	24.12	13.12	24.96	79.14	0.71
0.2					0.09	22.64	10.54	22.26	83.77	-0.57
	2				7.48	37.36	27.83	39.07	60.93	0.69
	4				0.45	24.12	13.12	24.96	79.14	0.71
	8				-3.45	15.50	4.18	15.98	103.72	0.75
		0.0			6.10	24.32	18.83	24.96	73.24	0.68
		0.1			0.45	24.12	13.12	24.96	79.14	0.71
		0.2			-3.53	23.89	8.72	24.96	82.70	0.73
			0.5		0.30	24.53	13.12	24.96	78.90	0.35
			1.0		0.45	24.12	13.12	24.96	79.14	0.71
			2.0		0.73	23.31	13.12	24.96	79.66	1.41
				0.25	-0.48	31.25	15.38	31.96	98.11	0.71
				0.50	0.45	24.12	13.12	24.96	79.14	0.71
				1.00	0.96	18.52	11.01	19.54	63.76	0.70

This table shows the effects of change in γ, I, k, σ_m^2 and c where the other parameters are σ_Z^2 = 5000, σ_a^2 = 1.0,

[17] Unlike in a market for beer or cars, competition between traders in a financial market is conducted via the market maker whose profit depends on being aware that some traders have privileged access to information. To the extent that the purpose of gathering information is to gain a relative advantage over other informed traders, an increase in the number of such traders would increase the speed and cost of the race between traders.

and $\sigma_T^2 = \sigma_a^2 + \sigma_m^2$. Net Profit reports the net profit earned by an informed trader. DR reports on the change in total rents earned by liquidity traders between disclosure regimes while Δ_Φ reports on the change in total information quality between disclosure regimes. The benchmark values used for the exogenous variables are reported in the second row of numbers. The remaining entries report only selected values in order to emphasize the parameter which differs from that benchmark. Interested readers are directed to a supplementary table in the Appendix which reports on the other endogenous variables since, together, they determine the equilibrium.

The fact that *DR* is positive implies that liquidity traders, in total, benefit from fuller disclosure. Liquidity traders benefit even more if there are more private traders who are informed, even if those traders experience a loss. Unlike informed traders who suffer from the reaction of the market maker, liquidity traders experience a net benefit from a reduction in the diversity of private information (i.e., an increase in *k*).

Hirshleifer [1971] noted that simple foreknowledge offers no social value: if one person knows something before somebody else then such knowledge can increase that person's profits, while decreasing somebody else's, but this profit represents a redistribution of rents rather than a creation of surplus value. If so then the resources used to gather such information are wasted in a social sense. Where Hirshleifer's analysis focused on the redistributive effects of changes in the price level due to changes in information, we note the effect of gathering private information on both price and the liquidity of a market. Table 3 suggests that liquidity traders benefit more from full disclosure when *c* is lower because the informed investors invest so much in information.

Table 3 offers a smaller puzzle because the change in the widely-used measure of price informativeness, Φ, does not seem to be closely related to the change in the rents earned by the liquidity traders. Despite the relatively small effect of σ_m^2 on *DR*, it seems to have a larger effect on Φ. An increase in *c* increases the cost of gathering information. $\gamma > 0$ also implies an investor's cost function is higher in the full disclosure setting relative to that in the limited disclosure setting. Yet the effects differ: an increase in c decreases DR and has nearly no effect on Φ while Φ seems relatively sensitive to a change in γ. These formal results may not be entirely unexpected since one of the measures is based on a statistical intuition and the other measure is based on some imperfect intuition about the behavior of simple investors. To the extent that disclosure regulation is designed to make prices more informative, with the simultaneous goals of allocating capital more efficiently and benefitting liquidity traders, this difference in results is troubling.

We think that the patterns displayed in these tables are general since they fit with intuition but it is possible that these patterns may be relevant only for a small set of parameter values. More than the specific numbers, we hope that these simulations help to refine a discussion of the relative importance of different types of changes. In this way, it may inform the kind of cost-benefit calculation advocated by Iannaconi [2011].[18] We also hope that, in conjunction with the supplementary table in the Appendix, these numbers show the covariation of many variables needed to maintain the equilibrium conditions.

6. Empirical Predictions

We have focused on the concepts of our model in order to clarify the relationships between traders and to emphasize the role of the equilibrium conditions. This section comments on some empirical predictions. This exercise is challenging because, even for prominent and important disclosure regulations in the US such as the Sarbanes Oxley Act or Regulation FD, many authors (e.g., Beyer et al. [2010, p. 320] or Leuz and Wysocki [2008, p. 45, 47]) note that the effects are debated vigorously more than a decade after being implemented. Our model and our results may offer some guidance to researchers studying these regulations; the apparent instability may be associated with the differences in the available information and the fact that different industries or different situations invoke different values of γ. Confirmation of such effects would require investigating the complementary effects, such as those discussed in our simulations.

We offer three other types of predictions, concerning the effects of

Earnings restatements,

Initial Public Offering (IPO),

Different trading systems.

Finally, we comment on how some effects may be evident in the cross-sectional variation evident in commonly-used control variables.

Consider the effect of an earnings restatement concerning some historic event. A restatement changes the bit of information disclosed and, for a given change in disclosure, the

[18] We note that the KPMG/FERF report also encourages policy makers to distinguish important and material disclosures from the kinds of less important but well-intentioned disclosures which clutter a report. Our model would need to be adapted to account for the effects of information being disaggregated before beginning such a cost benefit analysis.

direct effects of a *different* disclosure on inferences and on trading behavior are relatively easy to determine mechanically. This scenario has the added advantage that the reaction of a privately informed investor would often not vary with γ. In cases where private investors regret obtaining too much information in the past, such information would not be forgotten. Therefore, any effect beyond the mechanical effect should be associated with investors seeking additional private information. A potentially complicating feature of this attribution is that the restatement may occur under pressure (perhaps because private investors are displaying their previously-gathered independent information). Durnev and Mangen [2009] look at one aspect of this issue with little attention to the role of privately informed investors.

Secondly, a company faces many regulatory barriers before it is allowed to offer an IPO. While some authors note how the regulations can help or hurt the company (e.g., Leuz and Wysocki [2008, esp. section 2.4]), we note that a new company has little history for investors to use as a basis for their decisions. Therefore, privately gathered information can be expected to play a more important role, relative to a situation where an established company tries to raise capital to expand its current operations (such is as considered by Gao and Liang [2010]).[19] We conjecture that, in an IPO situation, fuller disclosure would lower the costs of gathering private information, perhaps by showing which potential conditions are not worth investigating. When γ is negative, our model shows that fuller disclosure increases the information gathered privately and increases the informativeness of prices. The fact that it is generally easier to obtain useful private information related to more traditional technologies, relative to industries which rely on more innovative or speculative technologies such as bio-technology or nano-technology, should also imply that the magnitude of this effect is larger in more traditional industries.[20]

[19] As contrast to the IPO situation, Gao and Liang [2010] consider a model where the firm must decide whether to raise capital to expand an existing project. This paper focuses on the regulatory trade-off between information which can create an adverse selection problem and information which can improve the efficiency of a market process. They demonstrate that when private investors use information not available to a firm and use that information to buy and sell shares which affects the market price, then the firm's can make better decisions. Our model assumes that the company's value is the result of the activities of its employees and managers who use their skills, effort and marketing information to select and implement a profitable business strategy.
The possibility that feedback from information generated by informed investors may affect the company's value would add a new layer to our model and add to any discussion of the effects of a change in disclosure regulations. Beyer et al. [2010, p. 319] notes that is difficult "to capture [the many interdependencies between disclosure, operating and financial decisions] in one model". Adding this layer to any model would certainly require that the actions of different types of traders be compatible in the sense described by the equilibrium conditions for that modified model.

[20] Within a country, different companies may also trade in different exchanges or in markets with different micro-market structures: Leuz and Wysocki [2008] discuss, for example, "pink sheets" and "over the counter" (OTC)

Thirdly, we suggest that the relationship between disclosure and private information can be investigated by using differences between countries. An effect should be especially significant if most of the investors are located in one country while most of the company's consumers or suppliers are located in another country: the difference in locations would increase the cost of gathering information independent of any disclosure. Some evidence of this effect exists internationally (Bae, Stulz, and Tan [2008], Nieuwerburgh and Veldkamp [2009], Tang [2011]) and within the United States (Malloy [2005]). The effect should also be larger if the company's main business activities are in a country with a poor information infrastructure, such as an emerging economy, and the research cited by Leuz and Wysocki [2008, p. 56] is encouraging.

Other evidence of the relationship between disclosure and private information gathering may be found in commonly-used control variables. Because they are control variables, empirical analysis may not offer a prediction for the sign of the coefficient. Our model suggests a systematic difference between small and large companies: large companies tend to be more stable and, in such cases, private information is unlikely to offer many surprising insights. Second, companies in riskier industries differ from those in other industries because, when estimating the value of a firm, an increase in the future risk reduces the relevance of any historic information which is disclosed. Therefore, disclosure may be important not because of the facts which are released but, as our model suggests, because the precision of the disclosure affects the private decision to collect more or less information. Therefore, we think that our model is more relevant to smaller firms and to those in riskier industries where any hidden variation in γ may be evident in a heteroscedastic effect of disclosure.

Some readers may wonder whether evidence for or against our model might be found in the large literature studying the activities of stock market analysts. They may be the most prominent publishers of privately gathered information and it is presumed that their advice affects trading behavior of some investors. Unfortunately, Beyer et al. [2010] notes that much of the recent research studies the motives of the analysts and that literature has not reached a consensus. Resolving that debate would remove some of the variation in the data hiding the

market structures. Since the role of the market maker is critical to many of our results, both in terms of b and in the effect on the informed traders' decision of how much to trade, these differences represent an additional source of predictions. Deriving the equilibrium conditions for these alternative market structures is a non-trivial task and we leave it as a future research project.

effects of less frequent, longer run changes in regulation. Our focus on the cost function is consistent with the idea that the quality of analysis varies with the resources available to the analyst (e.g., Clement [1999]).

7. Concluding Remarks

This paper examines how changes in corporate governance regulations, especially those related to disclosure, affect the market process. With many sources of information, a policy designed to improve information quality should combine the obvious direct effect with indirect effects, some of which are not commonly discussed. We show that the effects on total information quality depend on the interaction between public reports and the information obtained by private investor. Therefore, governance reforms can affect the level of private information by affecting the behavior of private investors and, indirectly, the market maker. The interaction of public disclosure and private information acquisition is more subtle because our analysis shows that the effect is ambiguous. We offer examples where an increase in the informativeness of public reports can lead to less *or* more informative private signals. The numerical examples also illustrate how different types of traders win or lose under different kinds of disclosure regimes in different information or trading environments.

We note that some analysts are beginning to worry about the overall level of disclosure. In July 2009, FASB created a Disclosure Committee to look at the general issue and, as part of its mandate, to study the issue of disclosure overload.[21] Overload can be interpreted as meaning either that more information has no effect because it is ignored or that it has the perverse effect of confusing investors so much that they make worse decisions (i.e., reduces trading profits or increases information cost or both). To the extent that disclosure regulation is intended to reduce information asymmetry, it would be unfortunate if disclosure overload increased an asymmetry. One implication of our model is that a discussion should distinguish between "liquidity traders", for whom overload may be a serious issue, and investors who actively seek extra information. Formally, our model assumes that informed investors can obtain information and convert it into trading decisions at a cost while liquidity traders have much more limited abilities to understand a disclosure. We do not consider a third category of investor who might become overloaded

[21] http://www.fasb.org/cs/ContentServer?c=FASBContent_C&pagename=FASB/FASBContent_C/NewsPage&cid=1176156338441.

under certain conditions.[22] Paredes [2003] discusses some of the legal and behavioral issues associated with information overload. Paredes [2003] and Beyer et al. [2010, esp. section 5.2] offer some suggestions on different types of reports and how investors might react to those differences.

A newer literature investigates the effects of written disclosures (e.g., Li [2008], Miller [2010], De Franco et al. [2011]). A written disclosure can be equivalent to a numerical disclosure but the impact of words may differ from that of numbers because, in addition to communicating a "good" signal or a "bad" signal, words can be vague. We suggest that the effect of vagueness depends on the sophistication of the investor and their access to information. A more sophisticated investor, faced with a non-manipulative written disclosure, can try to resolve the vagueness by collecting more information. An unsophisticated investor may look at the vagueness and react to it based on some combination of over-confidence and ambiguity aversion.[23]

Some work suggests that certain behavioral issues, such as loss aversion or ambiguity aversion (Caskey [2008], Easley and O'Hara [2010], De Franco et al. [2011]) cause market prices to be less informationally efficient than the standard models. The challenge to researchers is that the concept of ambiguity aversion can be interpreted in different ways and these differences may or may not make collecting more information a relevant response by an unsophisticated investor. Ambiguity aversion may represent a fundamental aspect of an investor's taste, comparable to risk aversion, or it may summarize an investor's response to the possibility that the firm's management is manipulating the information (e.g., Quiggin [1993, esp. p. 42- 43]). If ambiguity aversion is a response and if offering more trustworthy information in an easy-to-read format makes these behavioral issues less important then disclosing more information would also tend to reduce the significance of these so-called imperfections to the standard model. Miller [2010] offers some indirect support for this conjecture and for our model when he argues that a complex disclosure reduces the consensus of opinion amongst small

[22] If cross-sectional differences in the cost of information could be summarized by different values of c then the marginal cost of information approach the same level, i.e., $\exp(\gamma\sigma_a^2)$, as σ_i^2 approaches 0, for all informed investors. Since the marginal benefit of information would be the same for all traders, one can prove that one type of investor would obtain some information in equilibrium if and only if all other types would, though not necessarily the same amount.

[23] A comment by Peter Linneman suggests a complementary hypothesis: "in good times, a premium is attached to obscure statements but, in bad times, obscurity is punished" (December 3, 2008).

investors but not amongst large investors. Snow (2010) offers a conceptual analysis which, in part, shows how the value of information differs depending on whether the decision maker is risk averse or ambiguity averse. Thus, we conjecture that our ideas can be usefully applied to many types of models.

We assume, and past practice makes it reasonable, that a fact which is disclosed by a company is represented by a point estimate. A company which makes a forward-looking statement often add a comment (sometimes long and usually legalistic) with enough caveats and qualifications that the company cannot be held liable for missing their forecast. These caveats seem to vary little over time even if the level of uncertainty would tend to increase at any turning point in general economic conditions or when an industry experiences a dramatic change. Our model assumes that active investors are able to infer the precision of an estimate accurately and our comparative static analysis takes a long run perspective, in the sense that the inferences adapt to the changing conditions and regulations. Rather than asking investors to infer (σ_a^2, σ_m^2), it would be interesting to consider the effects of a forward-looking disclosure which also includes a time-varying notion of its precision. Statistically oriented investors might prefer to know a range or confidence interval for a forward looking statement but it may suffice for management to comment on whether the "degree of uncertainty" has changed relative to some historic base level. This kind of disclosure would send a signal to privately informed investors when there are extra benefits to gathering private information to answer questions which the company does not yet know how to answer.

In their lengthy review, Leuz and Wysocki [2008] note a puzzle: that regulation is generally tightest in developed countries where there may be least need. One way to extend our model would be to consider whether this puzzle is a consequence of the many ways in which the information infrastructure complements the regulations. These information sources may magnify the effects of the regulatory regime, in the ways we discuss above. These information sources can also be used by private investors or financial journalists to gather their own information about suspicious companies and, if the private suspicions pass some minimum threshold then a regulator can use their limited resources more effectively by investigating only those cases. The regulator may require companies to disclose the kinds of information which lower the costs of gathering private information as a helpful complement to the investigatory phase which precedes any prosecution. This kind of ex ante solution may be more effective than an imperfect ex post legal remedy (Leuz and Wysocki [2008, p. 72]) since the latter may prosecute innocent companies by mistake.

Any possible advice based on this model for managers is constrained by the assumptions of the model: e.g., that disclosure implies that their information advantage no longer exists. Our model offers more useful thoughts for the Board of Directors. In principle, the Board of Directors represents the interests of shareholders and the central theme of that representation is to ensure that the managers work to increase the value of the shares. Where other researchers have explored the contractual aspects of this principal-agent relationship, our paper indicates how a Board can help others participate in the oversight process. Specifically, the market price varies with all of the information available to investors. Some of that information comes from managers in response to the direction of the Board and the report by Iannaconi [2011] offers some suggestions. But some information also comes from outside the company; a Board can help by disclosing the kinds of information which lower the cost of private research.

APPENDIX

Derivation of Expressions for Trading Profits and Optimal Trading Rules

Given the conjectures shown in equation (6) and given her signals (y_a , y_m), the manager and the informed investors choose trading quantities to maximize their profits. The manager expects the price resulting from an order of z_m units to be

$$E[p_1 \mid y_a, y_m, z_m] = m_0 + y_a + bz_m + b\beta\sum_{i=1}^{I} E[y_i \mid y_a, y_m]$$

$$= m_0 + y_a + bz_m . \qquad \text{(A1)}$$

Since y_a , y_m and y_i are independent of each other, $E[y_i \mid y_a, y_m] = 0$, since the manager's trading profit is $\pi_m = (v - p_1)z_m$, the manager expects the trading payoff, based on her signals (y_a , y_m), to be

$$U_{m1}(y_a, y_m, z_m) = \{E[v \mid y_a, y_m] - E[p_1 \mid y_a, y_m, z_m]\}z_m$$

$$= (y_m - bz_m)z_m . \qquad \text{(A2)}$$

When the manager maximizes her payoff by choosing her trading amount z_m, the first-order condition yields

$$z_m(y_m) = y_m /(2b) . \qquad \text{(A3)}$$

The main text notes that informed investor *i* expects the orders placed by another informed investors to be

$$E[z_j \mid y_a, y_i] = \beta k(\hat{\sigma}_j / \sigma_i) y_i . \qquad \text{(A4)}$$

Therefore, the informed investor *i*'s expected price resulting from an order of z_i units, given his information (y_a , y_i), is

$$E[p_1 \mid y_a, y_i, z_i] = m_0 + y_a - b\{E[Z_l] - (z_i + \sum_{j \neq i} E[z_j \mid y_i] - E[z_m \mid y_i]\}$$

$$= m_0 + y_a + bz_i + b\sum_{j \neq i} E[z_j \mid y_i] \qquad \text{(A5)}$$

Given that the informed investor *i*'s trading profit is calculated as $\pi_i = (v - p_1)z_i$, his expectation of the trading payoff conditional on his information (y_a , y_i) is

$$U_{i1}(y_a, y_i, z_i) = \{E[v \mid y_a, y_i] - E[p_1 \mid y_a, y_i, z_i]\}z_i$$

$$= \{y_i - b\beta y_i \sum_{j \neq i} k(\hat{\sigma}_j / \sigma_i) - bz_i)z_i . \quad \text{(A6)}$$

An informed investor maximizes this expression by choosing

$$z_i(y_i) = [1 - b\beta \sum_{j \neq i} k(\hat{\sigma}_j / \sigma_i)]y_i / (2b) . \quad \text{(A7)}$$

Q.E.D.

Derivation of the Uninformed Investor's Posterior Mean of ε_{av}

The uninformed investor's posterior mean with respect to $\varepsilon_{av} = \varepsilon - y_a$ conditional on z_u is

$$\mu_{u1}(z_u) = E[\varepsilon_{av} \mid z_u] = E[\varepsilon_{av}] + \frac{Cov[\varepsilon_{av}, z_u]}{Var[z_u]}\{z_u - E[z_u]\} . \quad \text{(A8)}$$

where $z_u = Z_l - (z_m + \sum_{i=1}^{I} z_i)$ with Z_l ~ N$(0, \sigma_Z^2)$ and the conjectures $z_m = \alpha y_m$, $z_i = \beta y_i$.

Since $\varepsilon_{av} = \varepsilon - y_a$ ~ N$(0, \sigma_{a1}^2)$,

$$\mu_{u1}(z_u) = \frac{Cov[\varepsilon_{av}, (-\alpha y_m - \sum_{i=1}^{I} \beta y_i)]}{Var[Z_l - (\alpha y_m + \sum_{i=1}^{I} \beta y_i)]}\{z_u - E[z_u]\} . \quad \text{(A9)}$$

Given that the assumptions of $\varepsilon_{av} \mid y_m$ ~ N(y_m, σ_{m1}^2) and that $\varepsilon_{av} \mid y_i$ ~ N(y_i, σ_{i1}^2), that y_i ~ N(0, σ_i^2), that $Cov[y_m, y_i] = 0$, and that Z_l is not correlated with the other random variables in this model, and focusing on the case of a symmetric equilibrium in which all informed investors receive private signals from the same distribution ($\sigma_i^2 = \hat{\sigma}_j^2 = \sigma_j^2$) for all *j≠ i*, computing the relevant variance and covariance shows that

$$\mu_{u1}(z_u) = -\frac{\alpha\sigma_m^2 + \beta I \sigma_i^2}{\alpha^2\sigma_m^2 + \beta^2 I(1 + (I-1)k)\sigma_i^2 + \sigma_Z^2} z_u . \quad \text{(A10)}$$

Q.E.D.

Proof of Lemma 1

In a rational expectations equilibrium, the demand function for a manager, the demand function for an informed trader and the uninformed investor's posterior belief (shown on the left hand side of each of the following equations) must be consistent with the trader's preferred trading rule and the posterior belief (shown on the right hand side; equations (A3), (A7) and (A 10)) respectively. In other words,

$$z_m = \alpha y_m = \frac{1}{2b} y_m ,$$

$$z_i(y_i) = \beta y_i = \frac{1}{2b}[1 - b\beta \sum_{j \neq i} k(\hat{\sigma}_j / \sigma_i)] y_i \ ,$$

$$\mu_{u1}(z_u) = -bz_u = -\frac{\alpha\sigma_m^2 + \beta I \sigma_i^2}{\alpha^2\sigma_m^2 + \beta^2 I(1+(I-1)k)\sigma_i^2 + \sigma_Z^2} z_u \quad . \tag{A11}$$

Note that $\hat{\sigma}_j^2 / \sigma_i^2 = 1$ because, in a symmetric equilibrium, all informed investors want to make the same decisions. Solving this system of equations algebraically produces the following solutions:

$$\alpha = \frac{1}{2b},$$

$$\beta = \frac{1}{(2+(I-1)k)b},$$

$$b^2 = [\frac{1}{4}\sigma_m^2 + \frac{I}{(2+(I-1)k)^2}\sigma_i^2]\frac{1}{\sigma_Z^2} .$$

Q.E.D.

Proof of Proposition 1

In the strategic investor model with limited disclosure, the equilibrium price is

$$p_1 = m_0 + y_a + \frac{1}{2} y_m + \frac{1}{2+(I-1)k}\sum_{i=1}^{I} y_i - bZ_l \tag{A12}$$

The "correct" price is that which would be set by the market if all information were publicly disclosed. In this model, that price would be

$$p_1^* = E[v \mid y_a, y_m, \{y_i\}] = m_0 + y_a + y_m + \frac{1}{1+(I-1)k}\sum_{i=1}^{I} y_i \tag{A13}$$

We define the total information quality as the covariance between the "correct" price and the equilibrium price. Given $y_a \sim N(0,\sigma_a^2)$, $y_m \sim N(0,\sigma_m^2)$, $y_i \sim N(0,\sigma_i^2)$, $Cov(y_i, y_j) = k\sigma_i\sigma_j$, as well as y_a, y_m and y_i are independent of each other, Z_l is not correlated with the other random variables in this model, in a symmetric equilibrium in which all informed investors receive private signals from the same distribution ($\sigma_i^2 = \sigma_j^2$) for all $j \neq i$, we compute the covariance and show that the total information quality incorporated into the equilibrium market price is

$$\Phi \equiv Cov(p_1^*, p_1) = \sigma_a^2 + \frac{1}{2}\sigma_m^2 + \frac{I}{2+(I-1)k}\sigma_i^2 .$$

Q.E.D.

Proof of Lemma 2

For any given set of conditions summarized by b, β, σ_a^2, and $\hat{\sigma}_j^2$, an individual informed investor wants to maximize his *ex ante* expected net payoff

$$U_i^{net}(\sigma_i^2) = E[U_{i1}(y_a, y_i, z_i)] - \kappa_i(\sigma_a^2, \sigma_i^2)$$

$$= (1 - b\beta\sum_{j\neq i} k\sqrt{\hat{\sigma}_j^2/\sigma_i^2} - b\beta)\beta\sigma_i^2 - \exp(\gamma\sigma_a^2)(\sigma_i^2 + c(\sigma_i^2)^2) \quad \text{(A14)}$$

The first order condition with respect to σ_i^2 is

$$(1 - b\beta - \frac{1}{2}b\beta\sum_{j\neq i} k\sqrt{\hat{\sigma}_j^2/\sigma_i^2})\beta - \exp(\gamma\sigma_a^2)(1 + 2c\sigma_i^2) = 0 \cdot \quad \text{(A15)}$$

Notice that this condition recognizes the two benefits associated with increasing σ_i^2: that it improves the quality of information used when trading and that, for a given value of $\hat{\sigma}_j^2$ and depending on k, increasing σ_i^2 affects investor i's estimate of investor j's trading behavior. In a symmetric equilibrium, where $\sigma_i^2 = \hat{\sigma}_j^2 = \sigma_j^2$ for all $j \neq i$, substituting the equilibrium values derived in Lemma 1 shows that

$$\exp(\gamma\sigma_a^2)(1 + 2c\sigma_i^{*2}) = \frac{1}{2(2+(I-1)k)} \frac{\sigma_Z}{\sqrt{\frac{1}{4}(\sigma_T^2 - \sigma_a^2) + \frac{I}{(2+(I-1)k))^2}\sigma_i^{*2}}} .$$

(A16)

We can also substitute the same equilibrium values into equation (A14) to show that informed investor *i*'s *ex ante* expected net payoff is

$$U_i^{net}(\sigma_i^{*2}) = \frac{1}{(2+(I-1)k)^2}\frac{\sigma_Z \sigma_i^{*2}}{\sqrt{\frac{1}{4}(\sigma_T^2-\sigma_a^2)+\frac{I}{(2+(I-1)k))^2}\sigma_i^{*2}}} - \kappa_i(\sigma_a^2,\sigma_i^{*2}) \ . \qquad \text{(A17)}$$

Q.E.D.

Proof of Corollary 1

The proof of each part of this Corollary uses a characteristic of Lemma 2's first equation (and repeated in equation (A16)), which can also be expressed as

$$\exp(\gamma\sigma_a^2) = \frac{1}{2(1+2c\sigma_i^{*2})}\frac{\sigma_Z}{\sqrt{\frac{1}{4}(\sigma_T^2-\sigma_a^2)(2+(I-1)k))^2+I\sigma_i^{*2}}}$$

in order to isolate the relevant variables onto one or other side of the equal sign. The right hand side is a decreasing function of σ_i^{2*}.

For part (i), if $\gamma = 0$ then σ_a^2 appears only once and an increase in σ_a^2 requires a corresponding increase in σ_i^{2*} to reestablish equality.

For part (ii), σ_a^2 appears twice. If $\gamma < 0$ then an increase in σ_a^2 decreases the value of the left side of this equation. By itself, an increase in σ_a^2 increases the value of the right hand side of the equation. Therefore, an increase in σ_i^{2*} is required to reestablish equality. If $\gamma > 0$ then any prediction of the effect of σ_a^2 requires more information on the other parameters of the model.

For part (iii), an increase in *I* decreases the value of the right hand side. Therefore, a decrease in σ_i^{2*} is required to reestablish equality. The effect is bigger if *k* is closer to 1 or if $(\sigma_T^2 - \sigma_a^2)$ is bigger.

For part (iv), an increase in *k* decreases the value of the right hand side if *I* > 1. Therefore, a decrease in σ_i^{2*} is required to reestablish equality.

Q.E.D.

Proof of Lemma 3

With only two types of traders being relevant, the aggregate trading quantity absorbed by the market maker is

$$z_u^{'} = Z_I - \sum_{i=1}^{I} z_i^{'} . \tag{A18}$$

where $'$ denotes the solutions in the event of full disclosure. Since the market maker observes the two public signals (y_a , y_m) and the aggregate trading quantity, he uses these bits of information to set the market price, i.e.,

$$p_1^{'} = E_{u1}[v \mid y_a, y_m, z_u^{'}] = m_0 + y_a + y_m + \mu_{u1}(z_u^{'}) . \tag{A19}$$

As in the setting with limited disclosure, the conjecture of $\mu_{u1}(z_u^{'})$ is

$$\mu_{u1}(z_u^{'}) = -b^{'} z_u^{'} . \tag{A20}$$

The informed investor *i*'s expected price resulting from an order of $z_i^{'}$ units, given (y_a , y_m , y_i), is

$$E[p_1^{'} \mid y_a, y_m, y_i, z_i^{'}] = m_0 + y_a + y_m + b^{'} z_i^{'} + b^{'} \sum_{j \neq i} z_j^{'} . \tag{A21}$$

and his expectation of the trading profit is

$$U_{i1}^{'}(y_a, y_m, y_i, z_i^{'}) = \{ y_i - b^{'} z_i^{'} - b^{'} \sum_{j \neq i} z_j^{'} \} z_i^{'} . \tag{A22}$$

Using the same argument as in Lemma 1 when the disclosure was more limited, we conjecture that $z_i^{'} = \beta^{'} y_i$ for all *i* and that each trader makes symmetric inferences about the trading activity of the others. Maximizing the expected trading profit of an informed investor implies that $z_i^{'}(y_i) = \beta^{'} y_i = [1 - b^{'} \beta^{'} \sum_{j \neq i} k \sqrt{\hat{\sigma}_j^2 / \sigma_i^2}] y_i / (2b^{'})$. In equilibrium, $\sqrt{\hat{\sigma}_j^2 / \sigma_i^2} = 1$.

Making this optimal behavior consistent with their conjectured behavior implies that $\beta^{'} = 1/((2 + (I-1)k) b^{'})$. Hence, $z_i^{'}(y_i) = y_i / ((2 + (I-1)k) b^{'})$.

Using an argument parallel to that used in the derivation of equation (A8) above, the uninformed investor's posterior mean with respect to ε_{av} is

$$\mu_{u1}(z_u^{'}) = - \frac{\beta I [\sigma_i^{'}]^2}{\beta^2 I (1 + (I-1)k) [\sigma_i^{'}]^2 + \sigma_Z^2} z_u^{'} . \tag{A23}$$

In equilibrium, the uninformed investor's posterior mean must be consistent with the conjecture:

$$b' = \frac{\beta I[\sigma_i']^2}{\beta^2 I(1+(I-1)k)[\sigma_i']^2 + \sigma_Z^2}.$$

Substituting $\beta' = 1/((2+(I-1)k)b')$ yields

$$b' = \frac{\sqrt{I}}{2+(I-1)k}\frac{\sigma_i'}{\sigma_Z}. \tag{A24}$$

Hence we conclude that the informed investor *i*'s equilibrium demands is characterized by

$$z_i'(y_i) = \frac{1}{\sqrt{I}}\frac{\sigma_Z}{\sigma_i'}y_i. \tag{A25}$$

Q.E.D.

Proof of Proposition 2

In the strategic investor model with full disclosure, the equilibrium price is

$$p_1' = m_0 + y_a + y_m + \frac{1}{2+(I-1)k}\sum_{i=1}^{I} y_i - \frac{\sqrt{I}}{2+(I-1)k}\frac{\sigma_i'}{\sigma_Z}Z_l \tag{A26}$$

The "correct" price is that which would be set by the market if all information were publicly disclosed. In this model, that price would be

$$p_1^* = E[v \mid y_a, y_m, \{y_i\}] = m_0 + y_a + y_m + \frac{1}{1+(I-1)k}\sum_{i=1}^{I} y_i \tag{A27}$$

We define the total information quality as the covariance between the "correct" price and the equilibrium price. Given $y_a \sim N(0,\sigma_a^2)$, $y_m \sim N(0,\sigma_m^2)$, $y_i \sim N(0,[\sigma_i']^2)$, $Cov(y_i, y_j) = k\sigma_i'\sigma_j'$, as well as y_a, y_m and y_i are independent of each other, Z_l is not correlated with the other random variables in this model, in a symmetric equilibrium in which all informed investors receive private signals from the same distribution ($[\sigma_i']^2 = [\sigma_j']^2$) for all $j \neq i$, we compute the covariance and show that the total information quality incorporated into the equilibrium market price is

$$\Phi' \equiv Cov(p_1^*, p_1') = \sigma_a^2 + \sigma_m^2 + \frac{I}{2+(I-1)k}[\sigma_i']^2.$$

Q.E.D.

Proof of Lemma 4

In the strategic investor model with full disclosure, informed investor *i*'s expectation of the gross trading payoff at date one after deducting the information costs is

$$U_{i1}^{net'}(\sigma_i^{'})] = \left(1 - b^{'}\beta^{'} - b^{'}\beta^{'}\sum_{j\neq i} k\sqrt{[\hat{\sigma}_j^{'}]^2/[\sigma_i^{'}]^2}\right)\beta^{'}[\sigma_i^{'}]^2 - \exp(\gamma(\sigma_a^2+\sigma_m^2))([\sigma_i^{'}]^2 + c([\sigma_i^{'}]^2)^2)$$

(A28)

This expression implies that, given the market conditions defined by $(b^{'},\beta^{'},I,k,\hat{\sigma}_j^{'})$, the first order condition describing the choice of $[\sigma_i^{'}]^2$ by an optimizing informed investor is

$$\left(1 - b^{'}\beta^{'} - \frac{1}{2}b^{'}\beta^{'}\sum_{j\neq i} k\sqrt{[\hat{\sigma}_j^{'}]^2/[\hat{\sigma}_i^{'}]^2}\right)\beta^{'} = \exp(\gamma(\sigma_a^2+\sigma_m^2))(1+2c[\sigma_i^{'}]^2)\,. \tag{A29}$$

Substituting the characterizations found in Lemma 3 plus the symmetric equilibrium condition that $[\sigma_i^{'}]^2 = [\hat{\sigma}_j^{'}]^2 = [\sigma_j^{'}]^2$, we find that the equilibrium solution for $[\sigma_i^{'}]^2$ can be characterized by

$$\exp(\gamma(\sigma_a^2+\sigma_m^2))(1+2c[\sigma_i^{'*}]^2) = \frac{\sigma_Z/\sigma_i^{'*}}{2\sqrt{I}}\;. \tag{A30}$$

Using the same sequence of substitutions as used in the proof of Lemma 2 implies that the informed investor *i*'s *ex ante* expected net payoff in equilibrium is

$$U_i^{net'}(\sigma_i^{'*}) = \frac{1}{(2+(I-1)k)}\frac{1}{\sqrt{I}}\sigma_Z\sigma_i^{'*} - \exp(\gamma(\sigma_a^2+\sigma_m^2))([\sigma_i^{'*}]^2 + c([\sigma_i^{'*}]^2)^2)\,.$$

(A31)

Q.E.D.

Proof of Corollary 2

The proof of this Corollary uses a characteristic of Lemma 4's first equation (and repeated in equation (A30)) which can also be expressed as

$$\exp(\gamma(\sigma_a^2+\sigma_m^2)) = \frac{\sigma_Z}{(\sigma_i^{'*}(1+2c[\sigma_i^{'*}]^2))2\sqrt{I}}\;.$$

In this expression, the right hand side is a strictly decreasing function of $\sigma_i^{'*}$ while σ_a^2 and σ_m^2 appear only on the left hand side. Using a differential shows that equality is maintained if

$$\gamma \exp(\gamma(\sigma_a^2+\sigma_m^2))[d(\sigma_a^2+\sigma_m^2)] = -\frac{\sigma_Z/\sqrt{I}}{2(\sigma_i^{'*}(1+2c[\sigma_i^{'*}]^2))^2}\frac{d(\sigma_i^{'*}(1+2c[\sigma_i^{'*}]^2))}{d[\sigma_i^{'*}]^2}[d[\sigma_i^{'*}]^2]$$

(A32)

Therefore, computing $\partial[\sigma_i^{'*}]^2/\partial(\sigma_a^2+\sigma_m^2)$ is relatively easy, and it is positive (negative) if $\gamma<0$ ($\gamma>0$).

An increase in $\sigma_z/\sqrt{I}$ has a proportional effect on the right hand side of equation (A32). Therefore, for any given increase in $(\sigma_a^2+\sigma_m^2)$, an increase in $\sigma_z/\sqrt{I}$ reduces the change in $[\sigma_i^{'*}]^2$ required to reestablish equality: it shrinks $\partial[\sigma_i^{'*}]^2/\partial(\sigma_a^2+\sigma_m^2)$ toward 0.

Q.E.D.

Derivation of Equation (20) Concerning the Difference in Rents for Liquidity Traders ("DR")

Disclosure has no direct effect on the liquidity traders, by assumption, but it affects the other active players in the model directly which would affect *b* and the price paid in equilibrium. The total expected rents to all liquidity traders for the limited disclosure regime are

$$E(\pi_l) = E((v-p_1)Z_l) \quad . \tag{A33}$$

where the terminal value of the firm is $v = m_0 + \varepsilon$, $\varepsilon \sim \text{N}(0,\sigma_0^2)$ and the equilibrium price is characterized by

$$p_1 = m_0 + y_a - bz_u \, . \tag{A34}$$

A similar expression characterizes the equilibrium price for the full disclosure regime. In both the limited disclosure regime and the full disclosure regime, we assume that $Z_l \sim \text{N}(0,\sigma_Z^2)$, and Z_l is not correlated with the other random variables in this model. The demands by different types of traders are independent. Therefore, the expected rents to the liquidity trader in the limited disclosure and full disclosure settings are:

Limited Disclosure: $E(\pi_l) = E((v-p_1)Z_l) = E(p_1 Z_l) = -b\sigma_Z^2$,

Full Disclosure: $E(\pi_l^{'}) = E((v-p_1^{'})Z_l) = E(p_1^{'}Z_l) = -b^{'}\sigma_Z^2$. (A35)

Therefore, we estimate that the *difference* in rents accruing to liquidity traders created by fuller disclosure as

$$DR = -b^{'}\sigma_Z^2 - (-b\sigma_Z^2) = -(b^{'} - b)\sigma_Z^2 \ . \tag{A36}$$

The meaning of the expression for *DR* should be clarified because the behavior of liquidity traders was exogenously specified. Many researchers use this lack of specification to simplify non-critical aspects of a model and to focus attention on the more innovative aspects. Our limited model uses the simple idea that the decisions by liquidity traders to participate in the financial market reveal that any financial cost is balanced by some unspecified non-financial benefit. Therefore, Table 3 reports the *difference* in rents between disclosure settings rather than the gain or loss associated with a specific setting. This idea of balancing financial cost against non-financial benefit also means that our expression for *DR* should be interpreted as a middle estimate of the gains or losses experienced by liquidity traders. If a change in regulations benefits the mass of liquidity traders then we would expect them to react in ways which would increase their benefit, and if the change in regulations represents a cost for these traders then we would expect them to react in ways which would reduce their cost. In a more comprehensive model which included a more complete understanding of the changing motives and constraints for each of the many liquidity traders and which recognized the net surplus created by reallocating the limited available capital between competing projects, it may be possible to offer a more detailed social welfare analysis.

Q.E.D.

Table A1: Supplementary Information on the Equilibrium

Exogenous Variables					Limited Disclosure			Full Disclosure		
γ	I	k	σ_m^2	c	σ_i^{2*}	b	B	$[\sigma_i^{'*}]^2$	$b^{'}$	$\beta^{'}$
-0.2					6.98	0.050	8.73	8.21	0.035	12.34
0.0	4	0.1	1.0	0.50	6.02	0.046	9.39	6.14	0.030	14.27
0.2					5.17	0.043	10.11	4.55	0.026	16.57
	2				7.70	0.039	12.23	7.90	0.027	17.79
	4				6.02	0.046	9.39	6.14	0.030	14.27
	8				4.66	0.053	6.99	4.74	0.032	11.48
		0.0			6.05	0.045	10.06	6.14	0.035	14.27
		0.1			6.02	0.046	9.39	6.14	0.030	14.27
		0.2			5.98	0.043	8.84	6.14	0.027	14.27
			0.5		6.08	0.046	9.40	6.14	0.030	14.27
			1.0		6.02	0.046	9.39	6.14	0.030	14.27
			2.0		5.90	0.046	9.37	6.14	0.030	14.27
				0.25	9.36	0.057	7.56	9.48	0.038	11.48
				0.50	6.02	0.046	9.39	6.14	0.030	14.27
				1.00	3.83	0.037	11.69	3.95	0.024	17.79

This table shows the effects of change in γ, I, k, σ_m^2 and c where the other parameters are $\sigma_Z^2 = 5000$ and $\sigma_a^2 = 1.0$, and $\sigma_T^2 = \sigma_a^2 + \sigma_m^2$. The benchmark values used for the exogenous variables are reported in the second row of numbers. The remaining entries report only selected values in order to emphasize the parameter which differs from that benchmark.

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