Decision Facilitating Information and Induced Volatility: A Study of Tradeoffs in Accounting Disclosure

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ABSTRACT: Corporate managers often express concern about accounting induced volatility in financial statements. Accounting regulators, however, argue that the volatility in financial statements merely increases transparency by shining a light on risks that are inherent to the firm's business. We show that in many situations managerial concerns about volatility are justified because the information that is being provided actually magnifies rather than merely reflects the volatility in a firm's fundamentals. Corporate managers anticipate the magnified volatility and take preemptive actions to decrease the firm's exposure to the accounting treatment that induces volatility. These actions may not be in the best interests of external stakeholders, making disclosure costly while at the same time improving the decisions of external stakeholders. We develop and study the resultant tradeoff that accounting regulators should consider in setting accounting standards.

Keywords: accounting induced volatility; decision improving information; standard setting.

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1. INTRODUCTION

In this paper we develop and study an important tradeoff that historically has been ignored in setting accounting standards and disclosure requirements. The Financial Accounting Standards Board (FASB) stresses decision relevance to investors as a guiding principle for mandating accounting measurements and disclosures. But, it is often the case that accounting treatments that are intended to provide decision relevant information to external stakeholders have the side effect of magnifying the volatility in a firm's real financial condition. The added volatility may induce corporate managers to take preemptive actions to reduce the firm's exposure to the accounting treatment. Such actions could damage the payoffs to the same external stakeholders in whose interests the information is being provided. Thus there are both costs and benefits generated endogenously from such disclosure requirements. The benefits arise from improved decision making. The costs arise from anticipatory actions taken by corporate managers to reduce volatility. We construct the mechanism by which this occurs and analyze the implications that follow from such a tradeoff.

Corporate managers have often protested new accounting standards on the grounds that such measurements would increase the volatility of the firm's reported income and wealth. Such concerns were strongly expressed regarding the new standards for hedge accounting and for fair value accounting.[1] But, accounting regulators have given little weight to such volatility concerns arguing that the increased volatility merely reflects risks that are inherent to the firm's business and these risks were previously obscured by the prevalent accounting treatment.[2] There is much merit to FASB's position if the increased volatility is confined merely to accounting reports. But,

[1] For example, in a comment letter submitted to the FASB, a spokesperson for Intel Corporation stated: "Because of our strategic objectives and the nature of our operations, the recognition of fair value changes in net income would result in misleading and inappropriate volatility as these changes do not represent realized cash flows representative of our core cash generating activities." (Comment letter # 3 dated May 31st 2011 submitted to the FASB by Intel Corporation on the issue of Accounting for Financial Instruments.)

[2] See Beatty, Chamberlain and Magliolo (1996) for an articulation of these arguments.

if the proposed accounting treatment also causes increased volatility in the firm's fundamentals, there is cause for concern.

We construct and analyze a simple setting that allows us to parsimoniously demonstrate that the increase in volatility is not confined to the firm's financial reports, but is actually translated into added volatility in the firm's fundamentals. In our setting, a continuum of external stakeholders assess a firm's financial condition for the purpose of making individual decisions whose payoffs depend stochastically upon the firm's future wealth. *Collectively* these decisions significantly alter the financial condition of the firm. Thus, information provided to assess a firm's wealth changes the firm's wealth. Such two-way interactions are quite common. Potential senior employees may be concerned about a firm's financial health when choosing among competing employment opportunities. Customers may want to know that they are buying from a firm that will remain financially strong and viable in the future. Suppliers of raw materials and services to a firm may be concerned about a firm's ability to maintain a financially sound supply chain. Investors demand information about a firm's financial condition when explicitly or implicitly called upon to finance new investment projects. In all of the above settings, there is a two-way interaction between the firm and external agents. The firm's financial condition certainly affects the payoffs to actions taken by external stakeholders. But also the actions of external stakeholders significantly change the firm's financial condition.

The second part of the interaction is usually not easily visible, and not discussed by regulators, because in most situations a single agent's actions have a negligible effect on the firm's wealth. But, c*ollectively* the actions of a class of external stakeholders could be decisive for the firm's future viability. For example, consider the purchase decisions made by a firm's customers. No single customer's purchase may be large enough to materially impact the firm's bottom line, but the aggregate of customer purchases is critical to determining the financial health of the firm. In such two-sided interactions between the firm and its external stakeholders, the provision of information would add momentum to fluctuations in the firm's wealth. When the firm's financial situation looks good to external agents they take actions that make it even stronger, and a situation that doesn't look good could trigger a flight of financial capital, human capital, and abandonment by suppliers and customers that worsen the firm's financial condition.

In such situations, the provision of information to external users would certainly increase the volatility of the firm's real wealth from an *ex ante* perspective. But it is unclear why such increased volatility would be of concern to external stakeholders such as customers and suppliers. These agents act after the information is released, so as perceived by them, the information *reduces* uncertainty and helps them make better decisions. However, the increased *ex-ante* volatility would certainly be of concern to the firm's current owners. Corporate managers would then seek to reduce this volatility by taking anticipatory actions to diminish the firm's exposure to the accounting treatment that induces that volatility. For example, consider mark-to-market treatments (or fair value accounting) of a firm's cash flow hedges or other derivative trades, or a firm's holdings of liquidity motivated assets. Firms may change their hedging and speculation strategies and change their asset portfolios to reduce the short-term volatility caused by mark-to-market adjustments. Similarly, firms may change the compensation structure of its managers depending upon the accounting treatment of employee stock options.[3] Dye (2002) and Dye, Glover and Sunder (2015) describe how firms manipulate their real transactions to avoid bright line accounting classifications. If such anticipatory actions that are designed to protect/benefit the firm's current owners, have an adverse effect on external stakeholders the provision of decision facilitating information could become undesirable from the perspective of external stakeholders even though the information does improve their decisions.

The interactive effects described above, severely complicates the task of regulators who are charged with mandating accounting measurements and disclosures. Historically, the

[3] Such *real effects* of accounting measurement have been analytically studied in many contexts. See Kanodia [2006], and Kanodia and Sapra, [2016] for comprehensive surveys of the real effects literature. The empirical literature on "real earnings management" provides support for some of the theoretical findings. See Graham, Harvey and Rajgopal [2005], and Kraft, Vashishtha and Venkatachalam [2018].

Financial Accounting Standards Board (FASB) has emphasized "decision relevance" and has been strongly influenced by external users' demands for information. Our study shows that such an approach may not be an appropriate rule making strategy for at least two reasons. First, there is a time inconsistency problem (Kydland and Prescott, 1977). At the time that outside stakeholders need to make their decisions, the anticipatory actions taken by firms are sunk, so what is perceived to be optimal from an *ex post* perspective may actually be suboptimal from an *ex ante* perspective. Second, in most situations, individual external agents are so small that each individual's own action has no measurable effect on the firm's financial condition. Due to both reasons, the firm's financial condition would look like an exogenously fixed state of Nature. Given this perception, more information would always be preferred to less. Every external agent would rationally demand the information whose supply is under consideration, yet the public provision of that information could be disastrous.

Our paper adds new dimensions to the literature on the real effects of disclosure (Kanodia and Sapra (2016)). Prior literature has focused mainly on understanding what these real effects are and how they arise. There has been no attempt to simultaneously capture the beneficial effects of providing information that improves the decisions of external stakeholders. So a key tradeoff between the decision facilitating role of information and the real effects of information has not been developed. Here we focus on the real effects induced by added volatility. A good example of an accounting treatment that fits the analysis here is the mark-to-market treatment of a firm's assets and liabilities.

We show how improved external decisions and higher volatility are simultaneously induced by the provision of decision facilitating information, giving rise to a meaningful tradeoff with endogenous costs and benefits. We explicitly characterize sufficient conditions under which this tradeoff favors disclosure of some decision relevant information to external stakeholders and sufficient conditions under which the information should not be provided even though the information would improve the decisions of all external users. Additionally, we develop an upper bound to the amount of information that should be provided when the tradeoff favors some disclosure. We show that the more relevant the information is to external users and the more sensitive their decisions are to the information, the *lower* is that upper bound. These results are counter intuitive. They are driven by subtle endogenous costs that are induced by higher volatility in the firm's financial condition. We show that the two key factors that limit disclosure are the degree to which firms are averse to volatility in their financial condition and the extent to which assessments of the firm's financial condition are important to the actions to be taken by external stakeholders.

The tradeoffs due to the volatility increasing effect of information is also studied in Dang, Gorton, Holmstrom and Ordonez (2017) who argue that bank opacity is desirable because information causes fluctuations in the transaction value of assets and such fluctuation is detrimental to liquidity and insurance in financial markets. Similarly, in a macro-economic setting, Gaballo and Ordonez (2018) study how information improves resource allocation in the economy, but hampers the provision of insurance and liquidity. We take a slightly different approach to modeling the negative consequences of increased volatility. In our paper, volatility is costly because firms take anticipatory actions to reduce volatility and these actions are payoff decreasing to at least some of the firm's external stakeholders.

Ours is not the only paper to argue that the public release of information could be welfare decreasing. Hirshleifer (1971) was the first to argue that public information has negative consequences due to the destruction of risk sharing opportunities. Baiman (1975) found that in two player rivalry games each player would acquire less private information due to the rival's response to such information acquisition decisions. In a principal-agent setting, Arya, Fellingham, Glover and Sivaramakrishnan (2000) established that coarse and delayed information may be desirable because such information system design rewards agents for costly project search by adding slack to their operating budgets. Morris and Shin (2002) argued that, in a coordination game, public information is a double edged sword, improving individual decisions but coordinating actions away from fundamentals.[4] Plantin, Sapra and Shin (2008) and Allen and Carletti (2008) argue that providing fair value information on bank assets could trigger a downward spiral in asset values when markets are illiquid. Teoh (1997) shows how the disclosure of information can exacerbate free rider problems in team production.[5]

The remainder of this paper is organized as follows. Section 2 describes the economic setting that we analyze. A time line of events and a glossary of notation used are provided in Appendix A. Section 3 characterizes how external stakeholders use the information that is publicly provided to assess the firm's financial condition and make their own individual decisions. Section 4 describes the effect of these external actions on the firm's financial condition and the anticipatory actions taken by the firm to ameliorate these effects. Section 5 analyzes the tradeoff between the decision facilitating role and the volatility increasing role of accounting. Section 6 concludes. Proof of Propositions, where needed, are contained in Appendix B.

2. THE ECONOMIC SETTING

There are three dates: Date 0 is an initial date, date 1 is an interim date and date 2 is a terminal date. At the initial date, the firm chooses a portfolio of assets to hold. These assets change value over time and finally payoff at the terminal date becoming part of the firm's wealth

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[4] Gao (2008) developed conditions under which increasing the precision of public information would actually move stock prices closer to fundamentals in spite of the overweighting of public information in coordination games.

[5] Some other interesting papers along these lines are: Kanodia, Sapra and Venugopalan (2004) who show that when a firm's intangible investments cannot be measured with sufficient precision, it is better to leave them unreported. Cheynel (2013) used the Dye (1985) model to study the effects of disclosure on risk sharing and financing decisions. Zhang (2020) finds that when firms compete more fiercely for limited investment funds, the overweighting of public information due to strategic complementarity is exacerbated reducing firms' incentives to provide public disclosures. Zhang and Liang (2019) find that higher accuracy of public information may actually increase the probability of bank runs. Gao and Zhang (2018) study disclosure decisions with costly accounting manipulation in a setting where the incentive to manipulate is higher when other firms also manipulate.

at that date. At the interim date the firm discovers new information about the return to the risky asset which could be conveyed to external stakeholders.[6] These stakeholders use the information to assess the firm's terminal wealth and then choose their own individual actions. The firm's terminal wealth is determined at date 3 and consists of the payoff to the firm's asset portfolio as well as the collective effect of actions taken by the firm's external stakeholders at the interim date.

To fix ideas, we model the external stakeholders as the firm's customers, with the firm producing a single durable good. The benefits to purchase of the durable good depends partly upon the firm's ability to service, replace, and complement, the good over time which, in turn, is affected by the firm's continuing financial viability. Therefore, each customer individually assesses the firm's terminal wealth before making her purchase decision. In turn, the aggregate of these purchase decisions augments the firm's wealth and therefore customer assessments of the firm's terminal wealth alters the very object that they are assessing. We assume that there are a continuum of customers, uniformly distributed over the unit interval, who individually and independently decide how much of the firm's single good to buy. Let:

q_i = the amount purchased by customer i, and

$Q = \int_0^1 q_i di$ = the aggregate of customer purchases.

The above specification implies that each customer is infinitesimal so that her individual purchase has an insignificant effect on the firm's terminal wealth, even though the collective action of customers has a large effect.

We model the firm's asset portfolio choice in a simple way. The firm begins at date 0 with an endowment of m units of a riskless asset. One unit of the riskless asset held until the

[6] Such an information signal could emanate from a fair value accounting system where a firm's assets are marked-to-market at every reporting date.

terminal date produces one unit of wealth at the terminal date. However, the firm has the opportunity to convert some or all of its endowment into a risky illiquid asset whose prior expected return is greater than that of the riskless asset. Let z be the amount that the firm chooses to invest in the risky asset at date 0 and let $z\tilde{\theta}$ be the return at date 2. The firm's e*x post* terminal wealth is:

$$w = m - z + z\theta + Q \qquad (1)$$

Thus, the firm's terminal wealth depends partly upon a decision made by the firm's inside manager and partly upon the aggregate of decisions made by a continuum of outside stakeholders. These decisions are made sequentially. The inside decision is made at date 0, prior to the provision of the accounting information at the interim date, while external decisions are made after receipt of the accounting information.

We assume that all customers are identical. The payoff to a customer from purchasing the firm's good depends partly upon a known parameter η that describes how well the characteristics of the good produced by the firm fit the needs of the customer, and partly upon the financial strength of the firm. Let,

$$\tilde{A} \equiv \tau\eta + (1-\tau)\tilde{w} \qquad (2)$$

be the marginal benefit to purchasing a unit of the firm's good. The parameter $(1-\tau) \in (0,1)$, describes the relative extent to which customers are affected by the financial strength of the firm that supplies them[7]. The ex post payoff to a customer who purchases an amount q_i is:

[7] That customers are reluctant to place orders with suppliers who are perceived to be financially weak, is a well known empirical phenomenon. General Motors was faced with this predicament during the 2008-09 financial crisis. A possible reason is that the benefit to a customer from today's purchase depends partly upon future supplies of goods and services by the incumbent supplier, and the supplier's ability to perform in the future is affected by his current financial strength. Another possibility is that firms that are struggling financially may be motivated to cut corners and sacrifice attributes of the good that are not readily visible to customers.

$$u_i = Aq_i - \frac{1}{2}q_i^2 \qquad (3)$$

where $\frac{1}{2}q_i^2$ can be interpreted as the cost of using the good in whatever manner the customer uses it[8].

The information structure in the economy is as follows. The commonly known prior distribution of $\tilde{\theta}$ is Normal with mean μ and variance $\frac{1}{\alpha}$. We assume $\mu > 1$ so that investment in the risky asset is *a priori* desirable. The accounting system in place reports the firm's asset portfolio, so that the amounts z and $m - z$ of investments in the risky and safe assets at date 1 are publicly known. The risk free asset held by the firm does not change in value, only the risky asset does. Since the firm's wealth is relevant to customer purchase decisions, the decision facilitating information that firms could provide at the interim date is an estimate of the value of the risky asset at that date.[9] We assume that any such estimate is a noisy but unbiased version of its final value $z\theta$ at the terminal date. Since z is publicly known we model the interim information signal as:

$$\tilde{y} = \theta + \tilde{\varepsilon},$$

where $\tilde{\varepsilon}$ is distributed Normal with mean zero and variance $\frac{1}{\beta}$. Higher values of β represent more precise information, and the lowest value of β, i.e. $\beta = 0$ is equivalent to not providing the information signal.

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[8] The model of customers used here is a variation on the model of individual investment decisions with strategic complementarities in Angeletos and Pavan (2004). We do not explicitly model a price or a price setting mechanism for the good sold by the firm, as that would enlarge the model in ways that are not crucial to the development of the main ideas in this paper.

[9] Any mark-to-market adjustments to asset values and contingent liabilities clearly fits this description of decision facilitating information.

3. CUSTOMER PURCHASE DECISIONS

At the time that customers make their purchase decisions the firm's portfolio of assets is sunk, and known to each customer. Therefore, each customer takes the values of m and z as exogenously given. Let $E_i(\bullet)$ denote customer $i's$ expectation of a random variable conditional on the information she receives at date 1. In our model, all customers receive the same information, so the customer index i is redundant and will ultimately be discarded, but the customer index is helpful for the purpose of developing expectations of endogenous aggregate quantities. Given customer $i's$ expectation of $\tilde{A}$, her order quantity q_i is the unique solution to:

$$Max_{q_i}\ E_i(\tilde{A})q_i - \frac{1}{2}q_i^2 \tag{4}$$

The first order condition to (4) yields:

$$q_i = E_i(\tilde{A}) \ = \ \tau\eta + (1-\tau)E_i(\tilde{w}) \tag{5}$$

where w is the firm's terminal wealth as described in (1). Therefore,

$$q_i = \ \tau\eta + (1-\tau)[m - z + zE_i(\tilde{\theta}) + E_i(\tilde{Q})]\,. \tag{6}$$

In order to decide how much to purchase, each customer needs to form beliefs about the return to the risky asset and beliefs about the aggregate of other customer purchases. The presence of $E_i(Q)$ in individual customer purchase decisions implies the presence of strategic complementarities. The marginal benefit to purchasing the firm's good is increasing in the aggregate quantity purchased by other consumers. Beliefs about $\tilde{\theta}$ are Bayesian:

$$E_i(\tilde{\theta}) = E(\tilde{\theta} \mid y) \ = \ \frac{\alpha\mu + \beta y}{\alpha + \beta}, \forall i \tag{7}$$

$E_i(\tilde{Q})$ reflects customer $i's$ belief about how other customers will behave. Since other customers are also forming such beliefs in order to make their own decisions, in principle, $E_i(\tilde{Q})$

depends upon $i's$ beliefs of other customers' beliefs and $i's$ beliefs of other customers' beliefs of other customers' beliefs and so on up to an infinite hierarchy of higher order beliefs. Such higher order beliefs can be constructed iteratively, and in settings where the information of each customer contains some idiosyncratic elements, the construction is non-trivial as demonstrated in Morris and Shin [2002]. Since the phenomena we are studying in this paper do not depend upon the explicit construction of such a hierarchy of beliefs, we abstract away from it by assuming that customers have identical prior beliefs and that the public signal provided by the accounting system is the only source of new information. Thus it is common knowledge that all customers have exactly the same beliefs, in which case all higher order beliefs are equivalent to first order beliefs.

Because all customers are identical, $q_i = Q, \forall i$ and every customer knows the aggregate customer purchase from knowledge of her own behavior. It follows from (6) and (7) that $Q \equiv \int q_i di$ must satisfy:

$$Q = \tau\eta + (1-\tau)\left(m - z + zE(\tilde{\theta} \mid y)\right) + (1-\tau)\mathrm{Q}$$, which can be solved for Q:

$$Q = \frac{1}{\tau}\left[\tau\eta + (1-\tau)\left(m - z + zE(\tilde{\theta} \mid y)\right)\right] \tag{7}$$

Inserting this quantity into an individual customer's first order condition, as described in (6), it is easy to verify that $q_i = Q, \forall i$ and therefore each customer's purchase is also described by the right hand side of (7).[10]

[10] The aggregate quantity Q can equivalently be constructed via a guess and verify approach as in Angeletos and Pavan (2004). Such an approach requires the following steps: Begin with a conjectured linear relationship between Q, η and θ, next calculate beliefs about Q based on this linear relationship and the information signals available to individual customers, next use these beliefs to calculate individual purchase decisions, next aggregate these individual decisions to calculate the aggregate purchase quantity and lastly match coefficients to confirm the beginning conjecture.

4. THE FIRM'S ASSET HOLDING DECISION

The firm chooses its asset portfolio at date 0, anticipating customer assessments and purchase decisions at date 1. We first show that from the perspective of date 0, the provision of decision facilitating information at date 1, creates new risks for the firm and alters the risk return tradeoff that the firm must consider in determining how much to invest in the risky asset. It is easy to see from (7) that in the absence of the decision facilitating information to be provided at date 1,

$$q_i = Q = \frac{1}{\tau}\left[\tau\eta + (1-\tau)\left(m - z + z\mu\right)\right], \ \forall i, \tag{8}$$

which is a constant that is known at date 0. In such a regime, the variance of future wealth as assessed by the firm at date 0 is:

$$Var(\tilde{w}) = z^2\, Var(\tilde{\theta}) = z^2\, \frac{1}{\alpha} \tag{9}$$

But, when the decision facilitating information is provided at date 1, individual purchase decisions become a function of the interim signal y. From the perspective of date 0, the information provided at date 1 is a random variable. Therefore customer purchase decisions contingent on such information are also random variables. When the information is public, all customer decisions are affected the same way, resulting in a systematic shock to aggregate customer purchases. Instead of (9), the firm's assessment of uncertainty becomes:

$$Var(\tilde{w}) = z^2\, Var(\tilde{\theta}) + Var(\tilde{Q}) + 2zCov(\tilde{\theta}, \tilde{Q}), \tag{10}$$

The incremental uncertainty in the firm's wealth $Var(\tilde{Q}) + 2zCov(\tilde{\theta},\tilde{Q})$ is entirely due to the provision of the interim decision facilitating information. We refer to this incremental risk as "information risk."[11]

The firm anticipates the aggregate customer purchases described by (7) and calculates:

$$\begin{aligned} Var(\tilde{Q}) &= \left(\frac{1-\tau}{\tau}\right)^2 z^2\, Var\left(E(\tilde{\theta}\,|\,y)\right) \\ &= \left(\frac{1-\tau}{\tau}\right)^2 z^2 \left(\frac{\beta}{\alpha+\beta}\right)^2 Var(\tilde{y}) \\ &= \left(\frac{1-\tau}{\tau}\right)^2 z^2 \left(\frac{\beta}{\alpha+\beta}\right)\frac{1}{\alpha}, \qquad (11) \end{aligned}$$

and,

$$\begin{aligned} Cov(\tilde{\theta},\tilde{Q}) &= \left(\frac{1-\tau}{\tau}\right)\left(\frac{\beta}{\alpha+\beta}\right) z\, Cov(\tilde{\theta},\tilde{y}) \\ &= z\left(\frac{1-\tau}{\tau}\right)\left(\frac{\beta}{\alpha+\beta}\right)\frac{1}{\alpha} \qquad (12) \end{aligned}$$

So, inserting (11) and (12) into (10), the decision facilitating information causes the volatility of the firm's terminal wealth to become:

$$Var(\tilde{w}) = z^2 \frac{1}{\alpha}\left[1+\left(\frac{\beta}{\alpha+\beta}\right)\left[\left(\frac{1-\tau}{\tau}\right)^2 + 2\left(\frac{1-\tau}{\tau}\right)\right]\right]$$

Simplifying gives:

$$Var(\tilde{w}) = z^2 \frac{1}{\alpha}\left[1+\left(\frac{1-\tau^2}{\tau^2}\right)\left(\frac{\beta}{\alpha+\beta}\right)\right] \qquad (13)$$

[11] The label "information risk" is also used in the Finance literature.

The information risk imposed on the firm is:

$$Var(\tilde{Q}) + 2zCov(\tilde{\theta}, \tilde{Q}) \;=\; z^2 \left(\frac{1-\tau^2}{\tau^2} \right) \left(\frac{\beta}{\alpha+\beta} \right) \frac{1}{\alpha} \tag{14}$$

The factor $\frac{\beta}{\alpha+\beta}$ is strictly increasing in β, and the factor $\frac{1-\tau^2}{\tau^2}$ is strictly decreasing in τ and therefore strictly increasing in $(1-\tau)$. Recall that $(1-\tau)$ is the weight that consumer's put on the firm's wealth in making their purchase decisions. Then, it follows immediately from these observations that:

Proposition 1:

(i) More precise decision facilitating information, provided at the interim date, causes the firm's wealth to become more volatile from an ex-ante perspective.

(ii) The greater is the consumer's need to assess the firm's wealth, as captured by $(1-\tau)$*, the more volatile is the firm's wealth.*

(iii) Due to the information risk induced by the provision of decision facilitating information, the risk associated with the risky asset is much greater than the risk that is inherent to fluctuations in its market value.

The provision of decision facilitating information adds information risk to the usual risk of market fluctuations in the value of the risky asset. Since both components of risk are multiplicative in the amount of the risky asset, the usual risk-return tradeoff that investors face in making portfolio choices is altered. The weight $(1-\tau)$ that consumers put on the firm's wealth reflects the importance that consumers' attach to the firm's financial strength. This weight can also be interpreted in terms of the degree of strategic complementarity in consumer purchase decisions. Equation (13) indicates that the greater the degree of strategic complementarity the more volatile is the firm's wealth.

The above phenomena are not confined to the particular model we have formulated. They are generally true in any setting where the interaction between the firm and outside stakeholders is two-sided and sequential. *Any* new information that appears at date 1 is a random variable from the perspective of date 0. If the information is relevant to decisions that the firm's stakeholders need to make, it will cause variation in their decisions, and if the information is public such variations will be systematic across individual stakeholders. Thus, if aggregate external decisions affect the firm's wealth, the information provided to external stakeholders will induce systematic shocks to the firm's terminal wealth, thus increasing volatility.

The increased volatility described above is in the firm's *real* wealth. It is not merely an increase in the volatility of reports. But it is easy to see that the real increase in volatility is strongly correlated with the increased volatility in reported date 1 income. If one were to produce an income report at date 1, the report would simply reflect the change in the value of the firm's assets from date 0 to date 1. Sales to customers would be reported at date 2 as part of the firm's realized wealth. The initial value of the firm's assets is:

$$v_0 = m - z + z\mu$$

and the date 1 value of the firm's assets is:

$$v_1 = m - z + zE(\tilde{\theta} \mid y)$$

Therefore, the firm's reported income at date 1 would be:

$$\tilde{v}_1 - v_0 = z\,[E(\tilde{\theta} \mid y) - \mu]$$

and, from the perspective of date 0, the volatility in reported date 1 income is:

$$Var(\tilde{v}_1 - v_0) \;=\; z^2\, Var[E(\tilde{\theta} \mid \tilde{y})]$$

Since $Var(\tilde{Q}) \ = \left(\frac{1-\tau}{\tau}\right)^2 z^2\, Var\left(E(\tilde{\theta}\,|\,\tilde{y})\right)$, there is clearly a positive relationship between volatility in reported interim income and volatility in terminal wealth and the relationship is not merely a statistical correlation; It is causal.

How does the firm respond to the increased risk caused by the provision of decision facilitating information? We assume that the firm dislikes uncertainty in its real terminal wealth and has constant absolute risk aversion $\rho > 0$ [12]. Since $\tilde{w}$ is distributed Normal, the firm's objective function can be expressed as:

$$Max_z \left\{ E(\tilde{w}) - \frac{1}{2}\rho\, Var(\tilde{w}) \right\}$$

From (1) and (7),

$$E(\tilde{w}) \ = \ m - z + z\mu + \frac{1}{\tau}[\tau\eta + (1-\tau)(m - z + z\mu)]$$

$$= \ \frac{1}{\tau}[\tau\eta + (m - z + z\mu)] \qquad (15)$$

Inserting (13) and (15) into the firm's objective function and differentiating with respect to z gives the first order condition:

[12] Theoretically, a model of risk averse firms requires market frictions that prevent risk sharing. There are probably many other reasons why real world firms are averse to the volatility of their financial condition, and it is commonplace to observe firms taking costly actions to reduce such volatility. Risk aversion is merely a convenient and tractable way of modeling such aversion.

$$z = \frac{\frac{1}{\tau}(\mu - 1)}{\rho \frac{1}{\alpha}\left[1 + \left(\frac{1-\tau^2}{\tau^2}\right)\left(\frac{\beta}{\alpha+\beta}\right)\right]} \tag{16}$$

In the absence of decision facilitating information, the firm's investment in the risky asset would have been the larger quantity $z = \frac{\frac{1}{\tau}(\mu - 1)}{\rho \frac{1}{\alpha}}$. The following proposition summarizes this important result:

Proposition 2:

i. *The firm holds a different portfolio of assets in an accounting regime where decision facilitating information is provided to outside stakeholders, than it would hold in a regime where such information is not provided.*

ii. *The more precise is the decision facilitating information the greater is the shift in the firm's asset portfolio.*

The real effect that is captured in Proposition 2 is quite different from the usual way in which we think about decision facilitating information. That information provided to decision makers will influence their decisions is obvious. But here the decision maker, the firm, is not the agent that is being informed, and the altered decisions being described here occur *prior* to the actual release of information. Proposition 2 is another instance of the general idea that corporate decisions are not passive to the design of accounting regimes (see Kanodia and Sapra (2016)).[13]

[13] Models of real effects usually assume that the firm is sold in a capital market following the release of value relevant information. The real effects of disclosure arise because corporate managers are concerned with how their observable decisions are interpreted and priced in the capital market. Additionally, there is the Hirshleifer effect: Information released prior to the sale of a firm prevents the sharing or transfer of risk

Such real effects are critical to a welfare analysis of different accounting regimes, but are frequently and unfortunately ignored in policy debates. For example, fair value accounting is usually discussed as if the firm's assets remain exactly the same regardless of whether they are marked-to-market or not.

5. TRADEOFFS BETWEEN DECISION RELEVANCE AND VOLATILITY

Our characterization of the equilibrium decisions of both insiders and outsiders in response to the provision of decision facilitating information, allows us to endogenously quantify both the costs and benefits of disclosure. We proceed to study these costs and benefits from three different perspectives: (i) The *ex ante* perspective of the firm's owners, (ii) The *ex-ante* perspective of the firm's customers and (iii) The perspective of the firm's customers at the time they make their decisions. This last perspective allows us to identify a time inconsistency problem that accounting regulators must face. We think of the firm's owners/shareholders as internal stakeholders and the firm's customers as external stakeholders. We think that separately calculating their net benefits from the disclosure of information is useful because casual observation indicates that regulators, as well as the general public, tend to think about how different classes of people would be affected by some policy instrument that is being considered.[14] For example, in public debates about governmental intervention it is commonplace to hear about employers versus employees, owners versus customers, etc.

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from current owners to a bigger and less risk averse group in the capital market. We have taken a different, but equally credible route, in the present study.

[14] In the classical Arrow-Debreu general equilibrium theory every agent in the economy is both a consumer and an investor while the firm is simply a technology with no preferences. So a full blown analysis of social welfare would reflect the combined net benefits of producing, consuming and risk bearing of all the consuming agents in the economy. We do not attempt such a global welfare analysis here. Such a task, when combined with informational differences and

Since greater precision is analogous to more information, we formalize our analysis in terms of variations in the precision of information. If the net benefits to all classes of agents is uniformly declining in β, then providing the decision facilitating information is unambiguously harmful. If the net benefits to economic agents acting purely in their capacity as shareholders is declining in β, but the net benefit from a customer perspective is increasing in β then social planners would need to trade off these conflicting effects.

The shareholder perspective:

The net benefits of disclosure to the firm's current shareholders is simply the maximized value of its objective function at the equilibrium value of Q. Therefore, the effect of decision facilitating information on this class of stakeholders is described by:

$$\frac{\partial}{\partial\beta}\left\{Max_z\left(E(\tilde{w})-\frac{1}{2}\rho\,\mathrm{var}(\tilde{\mathrm{w}})\right)\right\}$$

where $E(\tilde{w})$ is as described in (15) and $\mathrm{var}(\tilde{w})$ is as described in (13). Using the envelope theorem, this derivative at the optimal value of z is:

$$-\frac{1}{2}\rho\, z^2\,\frac{1}{\alpha}\left(\frac{1-\tau^2}{\tau^2}\right)^2\frac{\partial}{\partial\beta}\left(\frac{\beta}{\alpha+\beta}\right) \;<\; 0 \qquad (17)$$

This gives us the following result:

Proposition 3

From the perspective of the firm's owners the net benefit to providing decision facilitating information to external stakeholders is strictly decreasing in the precision of the information.

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differences in opportunity sets would present many technical challenges. We leave this as a topic for future research. We thank an anonymous referee for bringing this point to our attention.

Hirshleifer (1971) was the first to describe the negative effects of public disclosure and Diamond (1985) and Kanodia and Lee (1998) exploited the Hirshleifer effect in characterizing the optimal disclosures of a firm. The analysis in these previous papers rests upon the destruction of risk sharing, where the risk is exogenously given. The result here is qualitatively different, in that it rests upon disclosure creating a new risk that we have called information risk, and we have assumed that such risk cannot be diversified away.

The customer perspective:

We now take a purely customer perspective and study whether their net benefit is increasing or decreasing in the precision of decision facilitating information. Borrowing from Angeletos and Pavan (2004), we think of the net benefit to this class of agents as simply the aggregate of their individual net payoffs from their purchase decisions. This aggregate net benefit is

$$\Omega \equiv A\int q_i di - \frac{1}{2}\int q_i^2 di$$

But since $q_i = Q, \ \forall i$, $\Omega \equiv AQ - \frac{1}{2}Q^2$. Inserting the expression for A gives:

$$\Omega = \left[\tau\eta + (1-\tau)(m - z + z\theta + Q)\right]Q - \frac{1}{2}Q^2 \quad ,$$

or, equivalently,

$$\Omega = \left[\tau\eta + (1-\tau)(m - z + z\theta)\right]Q - \frac{1}{2}(2\tau - 1)Q^2 \qquad (19)$$

It is instructive to first examine customer demands for information from the perspective of an individual customer at the date she makes her purchase decision. At that date she would view the firm's assets, which were chosen at date 0, as sunk and given. So each customer would compare the provision of decision facilitating information to its absence, taking the values of z and Q as exogenously given. In the absence of decision facilitating information, or equivalently when $\beta = 0$,

$$q_i \;=\; Q \;= \frac{1}{\tau}\left[\tau\eta + (1-\tau)\left(m - z + z\mu\right)\right], \;\; \forall i$$

Inserting this equilibrium value of Q in (19) gives that:

$$\Omega \;=\; \left[\tau\eta + (1-\tau)(m - z + z\theta)\right]\frac{1}{\tau}\left[\tau\eta + (1-\tau)(m - z + z\mu)\right] - \;\frac{2\tau - 1}{2\tau^2}\left[\tau\eta + (1-\tau)(m - z + z\mu)\right]^2$$

The above expression is an *ex post* calculation that depends upon the realized value of θ. Taking an expectation over θ, customer expected net benefits in the absence of decision facilitating information is, for each given value of z:

$$E(\Omega \,|\, z, \text{No information}) \;=\; \frac{1}{2\tau^2}\left(\tau\eta + (1-\tau)(m - z + z\mu)\right)^2 \qquad (20)$$

For expositional purposes, we next calculate aggregate customer net benefit when the decision facilitating information perfectly reveals the future value of θ. Knowledge of θ allows the customer to perfectly adjust his/her purchase quantity to fit the firm's financial situation. In this case, $q_i = Q = \frac{1}{\tau}\left[\tau\eta + (1-\tau)(m - z + z\theta)\right], \forall i$ and,

$$E(\Omega \,|\, \text{z, perfect information}) \;=\; \frac{1}{2\tau^2} E\left[[\tau\eta + (1-\tau)(m - z + z\theta)]^2\right]$$

$$= \;\frac{1}{2\tau^2}\left\{E[\tau\eta + (1-\tau)(m - z + z\theta)]\right\}^2 + \frac{1}{2\tau^2}\,\text{var}\left(\tau\eta + (1-\tau)(m - z + z\theta)\right)$$

$$= \frac{1}{2\tau^2}[\tau\eta + (1-\tau)(m - z + z\mu)]^2 + \frac{1}{2\tau^2}(1-\tau)^2 z^2 \frac{1}{\alpha} \qquad (21)$$

Comparing (21) to (20), it is clear that the second term in (21) represents the gain to customers from receiving perfect decision facilitating information. The gain is positive and proportional to $\frac{1}{\alpha}$, which is the extent of uncertainty reduction caused by the information.

Now, consider the case where the decision facilitating information is noisy. For given precision β of the information signal, we obtain:

Proposition 4:

The aggregate net benefit to consumers from providing decision facilitating information with precision β is:

$$E(\Omega \mid z,\ \beta) = \frac{1}{2\tau^2}\left[\tau\eta + (1-\tau)(m - z + z\mu)\right]^2 + \frac{1}{2\tau^2}(1-\tau)^2 z^2 \left(\frac{\beta}{\alpha+\beta}\right)\frac{1}{\alpha} \qquad (22)$$

As before, the first term in (22) is expected customer net benefit from purchases in the absence of decision facilitating information and the second term is the change in customer net benefits due to the noisy information. The change is positive and strictly increasing in β. Once again the benefit to customers is proportional to the uncertainty reduction $\frac{1}{\alpha} - \frac{1}{\alpha+\beta}$ = $\left(\frac{\beta}{\alpha+\beta}\right)\frac{1}{\alpha}$.

The above calculations imply that, at the time they choose their decisions, every customer would express a strong demand for decision facilitating information and would want that information to be as precise as possible. This is not surprising. Since the firm's assets and the size of the collective order quantity Q are viewed as exogenous variables that are beyond an individual customer's control the wealth of the firm is like a state of Nature, in which case Blackwell's theorem applies. More information is unambiguously preferred to less.

It is tempting for accounting regulators to accede to the sequentially rational demands of external stakeholders. The information is relevant, improves their decisions, and can be reliably provided. But, the larger wisdom dictates that regulators should take into account the effect of the firm's anticipatory actions on the net benefits of these same external stakeholders, given that such anticipatory actions would vary with the choice of an accounting regime. From such an *ex-ante* perspective, the firm's assets are not fixed and sunk. In Proposition 2 we established that the firm anticipates the information risk due to decision facilitating information, and the increased volatility that comes with it, and counters the increased volatility by shifting its portfolio holdings away from the risky asset. The more precise is the decision facilitating information the greater is the shift in the firm's asset portfolio. Given that $\mu > 1$, customer benefits decline when the firm decreases its investment in the risky asset, as can be seen from visual inspection of (22). So the increase in customer net benefits from providing decision facilitating information may no longer be true when the decline in z is taken into account. As in Kydland and Prescott (1977), there is a time inconsistency problem here. What is *ex-post* optimal for a group of economic agents may not be *ex-ante* optimal for that same group of economic agents.

Even if a regulator were to ignore the perspective of the firm's owners and focus entirely on the perspective of external stakeholders, the regulator faces the following tradeoff when determining how much decision facilitating information should be mandated. The expected payoffs to external stakeholders is strictly increasing in both z and β. More precise information (higher β) allows the stakeholder to better calibrate her decisions to the actual wealth of the firm. This is the decision facilitating role of information. A higher investment in the risky asset (higher

z) increases the expected payoff to the same stakeholder from every decision she could make. Unfortunately, when the regulator increases β the firm decreases z, setting up a tradeoff between one desirable variable and another.

Let β^* be the optimal amount of disclosure from a customer perspective. It is difficult to provide a closed form expression for β^*. However, we are able to establish three results that provide some partial insights into how much decision facilitating information should be provided from an *ex-ante* customer perspective: (i) We characterize sufficient conditions under which it is optimal to provide some positive amount of decision facilitating information, i.e., sufficient conditions under which $\beta^* > 0$. (ii) Given that some positive amount of decision facilitating information is desirable, we characterize an upper bound to the amount of information that should be provided. (iii) We characterize sufficient conditions under which it is optimal not to provide the decision facilitating information, i.e., sufficient conditions for $\beta^* = 0$.

Viewing z as an implicit function of β, as defined by (16), customer net benefits described in (22) consists of two additive terms. Denote the first term in (22) as $g(z(\beta))$ and the second term as $f(z(\beta), \beta)$, so that customer net benefit is expressed as: $\Omega(\beta) = g(z(\beta)) + f(z(\beta), \beta)$. Then the marginal effect of decision facilitating information on *ex-ante* customer net benefit is described by:

$$\Omega_\beta(\beta) = g_z z_\beta + f_z z_\beta + f_\beta \tag{23}$$

where these partial derivatives are described in equations (A1) through (A4) in the Appendix. Note that g_z and f_z are both strictly positive since they describe the beneficial effects of a higher amount of the risky asset, $z_\beta < 0$ describes the decrease in the amount of the risky asset caused by disclosure, and $f_\beta > 0$ describes the decision facilitating benefit from disclosure. This implies that the first term in (23), $g_z z_\beta < 0$ at all parameter values, while the second term, $f_z z_\beta + f_\beta$, is of ambiguous sign since it captures the two opposing effects of disclosure that were described earlier.

A sufficient (but not necessary) condition for $\beta^* > 0$ is obtained by finding conditions under which $\Omega_\beta > 0$ at $\beta = 0$. This approach yields:

Proposition 5:

A sufficient condition that guarantees that at least some decision facilitating information improves the aggregate net benefit of customers (i.e, a sufficient condition for $\beta^* > 0$ *) is:*

$$\left(\frac{1+\tau}{\tau}\right)\rho\left(\tau\eta+(1-\tau)m\right) + \left(\frac{1-\tau^2}{\tau^2}\right)\alpha(\mu-1)^2 < \frac{1}{2} \tag{24}$$

Condition (24) is difficult to interpret. Some insight is provided by examining the limit of the left hand side of (24) as $\tau \to 1$. If $m > \eta$ the left hand side of (24) is strictly decreasing in τ , and as $\tau \to 1$, $\left(\frac{1+\tau}{\tau}\right) \to 2$, and $\left(\frac{1-\tau^2}{\tau^2}\right) \to 0$. Therefore as $\tau \to 1$ (equivalently as $(1-\tau) \to 0)$ the sufficient condition described in (24) becomes: $2\rho\eta < \frac{1}{2}$. Therefore, providing at least some decision facilitating information is guaranteed to improve customer net benefit if $\rho\eta < \frac{1}{4}$, $m > \eta$, and τ is sufficiently close to 1 or, equivalently, $(1-\tau)$ is sufficiently close to 0. In other words, disclosure of information that facilitates the assessment of a firm's wealth is favored when the firm's wealth has a *low*, but non-zero, marginal effect on the payoff to the decisions made by external stakeholders.[15] Proposition 5 also implies that low values of $(\mu-1)$ and low values of ρ favor disclosure. These results appear to be counter

[15] An equivalent, and perhaps more intuitively understandable interpretation, is that disclosure of decision facilitating information is desirable from a customer perspective only when the strategic complementarity in customer purchases is low. We thank an anonymous referee for this suggestion.

intuitive. They are driven by subtle endogenous costs to disclosure. These costs arise due to the following causally linked chain of events: Disclosure of decision facilitating information causes volatility which causes the firm to reduce its investment in the risky asset, which decreases the firm's expected wealth, which decreases customer payoffs. Recall that $(\mu-1)$ is the expected return per unit of the risky asset and ρ is the firm's risk aversion. A lower value of $(\mu-1)$ makes the decrease in risky investment less costly, while low values of ρ make the firm's choice of z less sensitive to volatility. Both factors reduce the cost of disclosure. Additionally, lower weight on the firm's wealth (or lower strategic complementarity in customer purchase decisions) decreases volatility and decreases the cost of disclosure.[16]

Proposition 5 describes a sufficient, but not a necessary condition for some degree of disclosure to be beneficial. The proposition does not say that decision facilitating information should not be provided when $(1-\tau)$ is large. But, we establish in Proposition 6 below that there is an upper bound to the amount of decision facilitating information that should be provided when the weight that customers attach to the firm's wealth in making their purchase decisions exceeds a critical level. The upper bound on information decreases as the weight on the firm's wealth increases. The critical weight on the firm's wealth is $(1-\tau)=$ 0.293. When $(1-\tau)<0.293$ there is no such constraining upper bound on the amount of information that should be provided. The proof of Proposition 6 exploits the fact that because $g_z z_\beta < 0$ at all parameter values, it is necessary (but not sufficient) that $f_z z_\beta + f_\beta > 0$ for the optimal amount of disclosure to be non-zero. As shown in Proposition 6, if $(1-\tau)>0.293$ there is an interior maximal value of β at which this condition can be satisfied:

[16] At $(1-\tau)=0$ the cost of disclosure become zero, but the benefit to disclosure is also zero, since the firm's wealth no longer affects the customer.

Proposition 6:

If $\tau < \sqrt{1/2}$ *(i.e.if* $(1-\tau) > 0.293$*) and some amount of decision facilitating information improves the aggregate net benefits to customers, there is an upper bound to the amount of information that should be disclosed. The upper bound is described by:*

$$\beta^* < \frac{\alpha\tau^2}{1-2\tau^2}$$

The greater the value of $(1-\tau)$ *) the lower is the upper bound.*

It is easy to identify an upper bound in any decision problem that has an interior solution. The remarkable feature of the upper bound identified here is that it actually varies, and varies in a counter intuitive way with a parameter that describes how important the information is to the decision maker. The parameter $(1-\tau)$, which is the weight that consumers put on the firm's wealth, describes the degree to which the firm's wealth affects consumer purchase decisions. One would normally expect that the greater the importance of the object being assessed, the more precise we would want the information to be. The behavior of the upper bound suggests (but does not conclusively establish) that here the opposite is true. Another reason why the upper bound result is significant is that it is not clear why consumers would want only a limited amount of information. Our setting is like a cheap talk game, in the sense that there are no direct costs to disclosure. So, if information is useful, why not get an unlimited amount of it? In this sense, the upper bound described here is non-trivial. As in Proposition 5, the upper bound result is driven by the presence of subtle endogenous costs to disclosure and these costs increase with the same parameters that determine the importance of the information. The costs identified here are missing in most policy deliberations of mandatory disclosure requirements because it is assumed that firms' operations are invariant to the design of accounting regimes.

We now derive sufficient conditions under which the effect of disclosure on the firm's asset portfolio is so strong that the decision facilitating benefit of disclosure is completely overwhelmed and it is *ex-ante* optimal not to make any disclosure, regardless of how much weight customers place on the firm's wealth. Formally, we seek conditions under which $\Omega_\beta < 0, \ \forall\beta, \forall\tau$.

Proposition 7:

If $2\rho\eta > 1 + 2\alpha(\mu - 1)^2$ customers are best served by not disclosing any decision facilitating information at all, i.e. $\Omega_\beta < 0, \ \forall\{\beta, \tau\}$.

Recall that ρ is the degree to which the firm is risk averse. From (16) it is apparent that the more risk averse the firm is the greater is the amount by which the firm reduces its risky investment in response to increased volatility. Proposition 7 says that if the firm is very risk averse then its investment in the risky asset declines so sharply in response to the volatility induced by disclosure that the gain from better decision making is swamped. Note also that, while the previous two results on customer net benefits depend upon how much weight $(1-\tau)$ customers place on the firm's wealth, this weight plays no role in Proposition 7. This is because we have identified conditions under decision facilitating information should not be provided, *regardless* of how much weight customers place on the firm's wealth.

6. CONCLUDING REMARKS

In the debate surrounding the financial crises of 2007-09 two contrasting views of the role of accounting in economic activity were expressed. Consistent with the model in this paper, many in the professional community argued that marking-to-market (MTM) the assets of financial institutions was seriously contributing to the downward spiral in the economy and that this real effect more than offset the decision facilitating role of mark-to-market accounting.[17] Many in the academic community argued that MTM reports served only a messenger role providing timely and relevant information to stakeholders and that eliminating mark-to-market accounting was analogous to shooting the messenger.[18] The more general question is: Do accounting measurements and reports to external parties merely mirror the events occurring in a firm, or do they also contribute to shaping those events? Which perspective is more descriptive of real world economies has major implications for standard setting. This paper should be viewed as one example of how the "messenger" view of accounting could result in serious standard setting errors.

We make no attempt to provide any general principles that would apply across all kinds of disclosures in an economy where there are two way interactions between the firm and external stakeholders. The social costs and benefits of a mandated disclosure could be quite subtle and quite different for different kinds of disclosures, and regulators need to carefully assess them on a case by case basis before arriving at an appropriate accounting policy.

Two key ingredients in our model drive the negative results described in our paper. First, the actions taken by external stakeholders not only affect their own individual payoffs, they also significantly affect the financial well-being of the firm. Second, decisions are chosen sequentially: Outside stakeholders choose their actions after the accounting information arrives, but the firm chooses its action before the accounting measurement occurs and in anticipation of that measurement. We think that these ingredients are present in many settings. To the extent that this is true, the approach taken here should be useful for studying many specific accounting

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[17] For examples, see Forbes (2009), Wallision (2008a, 2008b) and Whalen (2008). Similar concerns were expressed by the American Bankers Association and by several participants in the US Congressional debates.

[18] For examples, see Barth, Beaver and Landsman (2001) and Barth (2006). Laux and Leuz (2009) argue that: "FVA is neither responsible for the crisis nor is it merely a measurement system that reports asset values without having economic effects of its own."

disclosures. Fair value disclosures of a firm's assets and liabilities, accounting for firms' hedging activities, and loan loss provisioning by banks are some promising areas of application. A promising line of empirical investigation would be to study changes in firms' investments following new accounting mandates that increase the volatility of income.

On a more speculative note, our analysis indicates that governmental use of subsidies and or guarantees that reduce volatility could usefully supplement accounting regulation and enable the disclosure of more decision relevant information. Casual observation indicates that some of this may be occurring in the banking and auto industries.[19]

[19] We thank an anonymous referee for this insight.

Appendix A: Time Line and Notation

Summary of Notation

Symbol	Description
q_i	Amount of the firm's good purchased by Customer
Q	Aggregate customer purchases
w	Firm's ex-post terminal wealth
z	Firm's investment in the risky asset
$\tilde{\theta} \sim \mathrm{N}(\mu, \frac{1}{\alpha})$	Per unit final return from the risky asset distributed Normally with mean μ and variance $\frac{1}{\alpha}$.
$\tilde{A} \equiv \tau\eta + (1-\tau)\tilde{w}$	Marginal benefit to customer from purchasing one unit of the firm's good.
η	Known parameter that describes how the characteristics of the good produced by the firm matches the needs of the customer
$(1-\tau) \in (0,1)$	Parameter that describes the relative extent to which customers are affected by the financial strength of the firm that supplies them.
$u_i = Aq_i - \frac{1}{2}q_i^2$	Ex-post payoff of the customer who purchases an amount q_i
$\Omega \equiv AQ - \frac{1}{2}Q^2$	Ex-post aggregate net benefits of the customer population.
$\tilde{y} = \theta + \tilde{\varepsilon}$	Interim unbiased noisy public information signal about θ, where $\tilde{\varepsilon}$ is distributed Normal with mean zero and variance $\frac{1}{\beta}$.
ρ	Firm's constant absolute risk aversion parameter

Timeline of Events

Initial Date 0
Regulator chooses precision β of the public information signal.
Firm is endowed with m units of the risky asset.
Firm chooses investment z in risky asset. Prior distribution of per unit final return θ from the risky asset is Normal with mean $\mu > 1$ and variance $\frac{1}{\alpha}$.
Interim Date 1
Noisy public information signal y about the final per unit return θ from risky asset is released.
Customers choose purchase quantity of good produced by firm.
Aggregate customer purchases Q is determined.
Terminal Date 2
Per unit final return θ from the risky asset and firm wealth $w = m - z + z\theta + Q$ are realized.

Appendix B: Proof of Propositions

Proof of Proposition 4:

As derived in (19):

$$\Omega \;=\; \left[\tau\eta + (1-\tau)(m - z + z\theta)\right]Q - \frac{1}{2}(2\tau - 1)Q^2 \tag{A1}$$

and, as derived in (7)

$$Q \;=\; \frac{1}{\tau}\left\{\,\tau\eta + (1-\tau)(m-z) + (1-\tau)z\,E(\theta\,|\,y)\right\} \tag{A2}$$

where,

$$E(\theta\,|\,y) = \frac{\alpha\mu + \beta y}{\alpha + \beta} \;=\; \frac{\alpha\{\theta - (\theta - \mu)\} + \beta\theta + \beta\varepsilon}{\alpha + \beta}$$

$$= \;\theta\; - \;\frac{\alpha(\theta - \mu) - \beta\varepsilon}{\alpha + \beta}$$

Substituting the above expression in (A2) gives,

$$Q = \frac{1}{\tau}\left[\tau\eta + (1-\tau)(m - z + z\theta)\right] - \left(\frac{1-\tau}{\tau}\right)z\left\{\left(\frac{\alpha}{\alpha+\beta}\right)(\theta - \mu) + \left(\frac{\beta}{\alpha+\beta}\right)\varepsilon\right\}$$

and,

$$\begin{aligned} Q^2 = \;& \frac{1}{\tau^2}\left[\tau\eta + (1-\tau)(\mathrm{m} - z + z\theta)\right]^2 \\ & - \frac{2(1-\tau)}{\tau^2}\,z\left[\tau\eta + (1-\tau)(\mathrm{m} - z + z\theta)\right]\left[\frac{\alpha}{\alpha+\beta}(\theta-\mu) - \frac{\beta}{\alpha+\beta}\varepsilon\right] \\ & + \left(\frac{1-\tau}{\tau}\right)^2 z^2\left(\frac{\alpha(\theta-\mu) - \beta\varepsilon}{\alpha+\beta}\right)^2 \end{aligned}$$

Inserting these values for Q and Q^2 into (A1) gives:

$$\Omega = \frac{1}{\tau}\left[\tau\eta + (1-\tau)(m - z + z\theta)\right]^2$$

$$- \left(\frac{1-\tau}{\tau}\right) z\left[\tau\eta + (1-\tau)(m - z + z\theta)\right]\left[\frac{\alpha(\theta-\mu)-\beta\varepsilon}{\alpha+\beta}\right]$$

$$- \left(\frac{2\tau-1}{2\tau^2}\right)\left[\tau\eta + (1-\tau)(m - z + z\theta)\right]^2$$

$$-\left(\frac{2\tau-1}{2\tau^2}\right)(1-\tau)^2 z^2\left[\frac{\alpha(\theta-\mu)-\beta\varepsilon}{\alpha+\beta}\right]^2$$

$$+ \left(\frac{2\tau-1}{2\tau^2}\right) 2(1-\tau)\, z\left[\tau\eta + (1-\tau)(m - z + z\theta)\right]\left(\frac{\alpha(\theta-\mu)-\beta\varepsilon}{\alpha+\beta}\right)$$

Collecting terms gives,

$$\Omega = \frac{1}{2\tau^2}\left[\tau\eta + (1-\tau)(m - z + z\theta)\right]^2$$

$$-\left(\frac{2\tau-1}{2\tau^2}\right)(1-\tau)^2 z^2\left[\frac{\alpha(\theta-\mu)-\beta\varepsilon}{\alpha+\beta}\right]^2$$

$$+ \left(\frac{1-\tau}{\tau}\right)^2 z\left[\tau\eta + (1-\tau)(m - z + z\theta)\right]\left(\frac{\alpha(\theta-\mu)-\beta\varepsilon}{\alpha+\beta}\right)$$

Taking an expectation over the random variables θ and ε gives,

$$E(\Omega \mid z,\ \text{noisy information}) \ = \ \frac{1}{2\tau^2}\left[\tau\eta + (1-\tau)(m - z + z\mu)\right]^2 \ \frac{1}{2\tau^2}(1-\tau)^2 z^2 \frac{1}{\alpha}$$

$$-\left(\frac{2\tau-1}{2\tau^2}\right)(1-\tau)^2 z^2 \left[\left(\frac{\alpha}{\alpha+\beta}\right)^2 \frac{1}{\alpha} + \left(\frac{\beta}{\alpha+\beta}\right)^2 \frac{1}{\beta}\right]$$

$$-\left(\frac{1-\tau}{\tau}\right)^2 z\, Cov\left((1-\tau)z\theta\,,\frac{\alpha(\theta-\mu)-\beta\varepsilon}{\alpha+\beta}\right),$$

where we have used the statistical facts that for any two random variables x and y, $E(x^2) \ = \ \left[E(x)\right]^2 + Var(x)$ and $E(xy) = E(x)E(y) + Cov(x,y)$. Simplifying and collecting terms gives,

$$E(\Omega \mid z,\ \text{noisy information}) \ = \ \frac{1}{2\tau^2}\left[\tau\eta + (1-\tau)(m - z + z\mu)\right]^2$$

$$+ \ \frac{1}{2\tau^2}(1-\tau)^2 z^2 \left[\frac{1}{\alpha} \ - \ (2\tau-1)\frac{1}{\alpha+\beta} \ - \ 2(1-\tau)\frac{1}{\alpha+\beta}\right]$$

which simplifies to:

$$E(\Omega \mid z,\ \text{noisy information}) \ = \ \frac{1}{2\tau^2}\left[\tau\eta + (1-\tau)(m - z + z\mu)\right]^2$$

$$+ \ \frac{1}{2\tau^2}(1-\tau)^2 z^2 \left(\frac{\beta}{\alpha+\beta}\right)\frac{1}{\alpha}$$

Q.E.D.

<u>Proof of Proposition 5:</u>

Let β^* be the optimal amount of disclosure. A sufficient (but not necessary) condition for $\beta^* > 0$ is that $\Omega_\beta > 0$ at β=0. Therefore we seek conditions under which $\Omega_\beta \equiv \ g_z z_\beta + \ f_z z_\beta + \ \ f_\beta \ > \ 0$ at $\beta = 0$. From (22) and (16) we obtain:

$$g_z(\mathrm{z}) \ = \ \left(\frac{1-\tau}{\tau^2}\right)\left(\tau\eta + (1-\tau)m\right)\left(\mu - 1\right) \ + \ \left(\frac{1-\tau}{\tau}\right)^2 z\left(\mu-1\right)^2 \ > \ 0 \qquad \text{(A3)}$$

$$f_z(z,\beta) \;=\; z\left(\frac{1-\tau}{\tau}\right)^2\left(\frac{\beta}{\alpha+\beta}\right)\frac{1}{\alpha} \;>\; 0 \tag{A4}$$

$$f_\beta(z,\beta) \;=\; \frac{1}{2}z^2\left(\frac{1-\tau}{\tau}\right)^2\frac{1}{\left(\alpha+\beta\right)^2} \;>\; 0 \tag{A5}$$

and,

$$z_\beta(\beta) \;=\; -\,\frac{\left(\frac{1-\tau^2}{\tau^2}\right)\left(\frac{1}{(\alpha+\beta)^2}\right)(\mu-1)}{\frac{\tau\rho}{\alpha^2}\left[1+\left(\frac{1-\tau^2}{\tau^2}\right)\left(\frac{\beta}{\alpha+\beta}\right)\right]^2} \;<\; 0 \tag{A6}$$

These calculations imply the following the following limits as $\beta \to 0$:

From (16), $z \to \dfrac{\alpha(\mu-1)}{\tau\rho}$,

$$z_\beta \;\to\; -\frac{(\mu-1)\left(\frac{1-\tau^2}{\tau^2}\right)}{\tau\rho}\;,$$

$$g_z \;\to\; \left(\frac{1-\tau}{\tau^2}\right)\big(\tau\eta+(1-\tau)m\big)(\mu-1) \;+\; \left(\frac{1-\tau}{\tau}\right)^2(\mu-1)^3\left(\frac{\alpha}{\tau\rho}\right),$$

$$f_z \to 0,$$

$$f_\beta \to \frac{1}{2\tau^2\rho^2}\left(\frac{1-\tau}{\tau}\right)^2(\mu-1)^2$$

Therefore $g_z z_\beta + f_z z_\beta + \;f_\beta \;>\; 0$ at $\beta = 0$ if and only if:

$$\frac{1}{2\tau^2\rho^2}\left(\frac{1-\tau}{\tau}\right)^2(\mu-1)^2 \;>\; \left(\frac{1-\tau}{\tau^2}\right)\big(\tau\eta+(1-\tau)m\big)(\mu-1)^2\left(\frac{1-\tau^2}{\tau^2}\right)\frac{1}{\tau\rho}$$
$$+\;\left(\frac{1-\tau}{\tau}\right)^2(\mu-1)^4\left(\frac{1-\tau^2}{\tau^2}\right)\frac{\alpha}{\tau^2\rho^2}$$

Dividing both sides by $(\mu-1)^2$ and multiplying both sides by $\tau^2\rho^2$, the above inequality becomes:

$$\frac{1}{2}\left(\frac{1-\tau}{\tau}\right)^2 \ > \ \rho\left(\frac{1-\tau}{\tau}\right)\left(\tau\eta+(1-\tau)m\right)\left(\frac{1-\tau^2}{\tau^2}\right) \ + \ \alpha\left(\frac{1-\tau}{\tau}\right)^2(\mu-1)^2\left(\frac{1-\tau^2}{\tau^2}\right)$$

Dividing both sides by $\left(\frac{1-\tau}{\tau}\right)^2$ we obtain $g_z z_\beta + f_z z_\beta + \ f_\beta \ > \ 0$ at $\beta = 0$ if and only if for each $\tau \in (0,1)$:

$$\frac{1}{2} \ > \ \rho\left(\frac{\tau}{1-\tau}\right)\left(\tau\eta+(1-\tau)m\right)\left(\frac{1-\tau^2}{\tau^2}\right) \ + \ \alpha\,(\mu-1)^2\left(\frac{1-\tau^2}{\tau^2}\right),$$

which is equivalent to:

$$\frac{1}{2} \ > \ \rho\left(\frac{1+\tau}{\tau}\right)\left(\tau\eta+(1-\tau)m\right) \ + \ \alpha\left(\frac{1-\tau^2}{\tau^2}\right)(\mu-1)^2$$

where we have used: $\left(\frac{\tau}{1-\tau}\right)\left(\frac{1-\tau^2}{\tau^2}\right) \ = \ \left(\frac{\tau}{1-\tau}\right)(1+\tau)(1-\tau)\frac{1}{\tau^2}$

Q.E.D.

Proof of Proposition 6:

If $\beta*$ is the optimal amount of disclosure, $\beta*$ must satisfy the first order condition $\Omega_\beta(\beta*) \ = \ g_z z_\beta \ + \ f_z z_\beta + f_\beta \ \geq \ 0$. Since $g_z z_\beta \ < \ 0, \ \forall\beta$ and at all parameter values, it is necessary that $f_z z_\beta + f_\beta \ > \ 0$ at $\beta = \beta^*$. We calculate $f_z z_\beta + f_\beta$ below: Insert the optimal value of z as described in (23) into the expression for $f(z,\beta)$. This yields,

$$f(z(\beta),\beta) \;=\; \frac{1}{2}\left(\frac{1-\tau}{\tau}\right)^2 \frac{(\mu-1)^2}{\tau^2\rho^2}\left[\frac{\dfrac{\beta}{\alpha+\beta}}{\dfrac{1}{\alpha}\left[1+\left(\dfrac{1-\tau^2}{\tau^2}\right)\left(\dfrac{\beta}{\alpha+\beta}\right)\right]^2}\right]$$

$$=\; \frac{1}{2}\left(\frac{1-\tau}{\tau}\right)^2 \frac{(\mu-1)^2}{\tau^2\rho^2}\frac{1}{L(\beta)}$$

where:

$$L(\beta) \;\equiv\; \frac{\dfrac{1}{\alpha}\left[1+\left(\dfrac{1-\tau^2}{\tau^2}\right)\left(\dfrac{\beta}{\alpha+\beta}\right)\right]^2}{\left(\dfrac{\beta}{\alpha+\beta}\right)}$$

$$=\; \frac{1}{\alpha}\left[1+2\left(\frac{1-\tau^2}{\tau^2}\right)\left(\frac{\beta}{\alpha+\beta}\right)+\left(\frac{1-\tau^2}{\tau^2}\right)^2\left(\frac{\beta}{\alpha+\beta}\right)^2\right]\left[\frac{\alpha+\beta}{\beta}\right]$$

$$=\; \frac{1}{\alpha}\left[\left(\frac{\alpha+\beta}{\beta}\right) \;+\; 2\left(\frac{1-\tau^2}{\tau^2}\right) \;+\left(\frac{1-\tau^2}{\tau^2}\right)^2\left(\frac{\beta}{\alpha+\beta}\right)\right]$$

Differentiating gives:

$$L'(\beta) \;=\; -\frac{1}{\beta^2} \;+\left(\frac{1-\tau^2}{\tau^2}\right)^2\frac{1}{(\alpha+\beta)^2}$$

Using $f_z z_\beta + f_\beta \;=\; \dfrac{\frac{1}{2}\left(\frac{1-\tau}{\tau}\right)^2\left(\frac{\mu-1}{\tau\rho}\right)^2\left(-L'(\beta)\right)}{\left(L(\beta)\right)^2}$ and inserting the expressions for

$L(\beta)$ and $L'(\beta)$ yields:

$$f_z z_\beta + f_\beta = \left[\frac{1}{2}\left(\frac{1-\tau}{\tau}\right)^2\left(\frac{\mu-1}{\tau\rho}\right)^2\right]\left[\frac{1}{\beta^2}-\left(\frac{1-\tau^2}{\tau^2}\right)^2\frac{1}{(\alpha+\beta)^2}\right]\left[\frac{\frac{\beta}{\alpha+\beta}}{\frac{1}{\alpha}\left[1+\left(\frac{1-\tau^2}{\tau^2}\right)\left(\frac{\beta}{\alpha+\beta}\right)\right]^2}\right]^2$$

Since the first and third factors in the above expression are strictly positive, $f_z z_\beta + f_\beta > 0$ if and only if $\frac{1}{\beta^2}-\left(\frac{1-\tau^2}{\tau^2}\right)^2\left(\frac{1}{(\alpha+\beta)^2}\right) > 0$, which is equivalent to $\frac{1-\tau^2}{\tau^2} < \frac{\alpha+\beta}{\beta}$.

Therefore, a necessary (but not sufficient) condition for $\beta^* > 0$ is:

$$\frac{1}{\tau^2}-2 < \frac{\alpha}{\beta} \qquad \text{(A7)}$$

Now, $\frac{1}{\tau^2}-2$ is arbitrarily large as $\tau \to 0$, is strictly decreasing in τ, equals 0 at $\tau = \sqrt{1/2}$ and is < 0 at all $\tau > \sqrt{1/2}$. Therefore the necessary condition described in (A7) is satisfied at all values of β if $\tau > \sqrt{1/2}$ or equivalently if $(1-\tau) < 0.293$. However, if $\tau < \sqrt{1/2}$, i.e., if $(1-\tau) > 0.293$ the necessary condition is satisfied only if $\beta < \frac{\alpha\tau^2}{1-2\tau^2}$, which must then be an upper bound for β^* when $(1-\tau) > 0.293$. The second part of Proposition 6 follows from the fact that since the left hand side of (A7) is strictly decreasing in τ it must be strictly increasing in $(1-\tau)$.

Q.E.D.

Proof of Proposition 7:

We wish to find conditions under which $\Omega_\beta < 0, \ \forall\beta, \forall\tau$. Totally differentiating Ω with respect to β yields (with the aid of *Mathematica)*:

$$\Omega_\beta(\beta) = \frac{\left(\alpha(\mu-1)(\tau-1)\right)^2}{2\rho^2\tau(\beta+\alpha\tau^2)^3}\left[\alpha\tau\, h(\tau) + k(\tau)\beta\right]$$

where,

$$h(\tau) \equiv 2\alpha(\mu-1)^2(\tau^2-1) + \tau[\tau+2\rho(1+\tau)(m\tau-m-\eta\tau)], \text{ and}$$

$$k(\tau) \equiv 2m\rho(\tau^2-1) + \tau[2\tau^2-1-2\eta\rho(1+\tau)+2\alpha(\mu-1)^2(\tau^2-1)]$$

Neither $k(\tau)$ nor $h(\tau)$ depends upon β and also all factors multiplying these functions are strictly positive. Therefore if both functions $h(\tau)$ and $k(\tau)$ are strictly negative over the interval $\tau \in [0,1]$ then $\Omega_\beta < 0, \forall\tau, \forall\beta$. Notice that both $k(\tau)$ and $h(\tau)$ are polynomials of degree 3. We use Descartes' Rule of Signs[20] to argue that under the stipulated condition of the proposition, *viz.* $2\rho\eta > 1+2\alpha(\mu-1)^2$, both these polynomials are indeed strictly negative over the interval $\tau \in [0,1]$. Collecting coefficients, gives:

$$k(\tau) = 2[1+\alpha(\mu-1)^2]\tau^3 + 2\rho(m-\eta)\tau^2 - [2\alpha(\mu-1)^2+1+2\rho\eta]\tau - 2m\rho$$

In the above polynomial expression the coefficient of τ^3 is strictly positive and the coefficient of τ is strictly negative. Therefore, regardless of whether the coefficient of τ^2 is positive or negative, there is only one change of sign in the polynomial. Therefore, there is exactly one positive real root or no positive real root of the polynomial. We argue that given that $\rho\eta > \frac{1}{4}$, as implied by the stipulated condition of the proposition, $k(\tau)$ cannot have a positive real root.

[20] Descartes' Rule of Signs says that the number of positive real roots of a polynomial is either equal to the number of variations in sign of the polynomial or else less than the number of variations by a positive even integer.

Examine the end points of the interval containing the feasible values of τ. At $\tau = 1$, $k(\tau) = 1 - 4\rho\eta \ < \ 0$ since $\rho\eta \ > \ \frac{1}{4}$. At $\tau = 0$, $k(\tau) < 0$. Therefore there cannot be exactly one positive real root of the polynomial in the interval $[0,1]$, in which case there are no positive real roots implying that $k(\tau) \ < \ 0, \forall \tau \in [0,1]$.

Now, $h(\tau)$ is also a polynomial of degree three and can be expressed as:

$$h(\tau) \ = \ 2\rho(m-\eta)\tau^3 \ + \ [2\alpha(\mu-1)^2 + 1 - 2\rho\eta]\tau^2 \ - \ (2\rho m)\tau \ - \ 2\alpha(\mu-1)^2$$

Given that $2\rho\eta \ > \ 1 + 2\alpha(\mu-1)^2$ the coefficient of τ^2 is negative. So, if $m \le \eta$ there is no change of signs in the coefficients of the polynomial or if $m > \eta$ there is exactly one change in the signs of the coefficients. So, either there are no positive real roots of the polynomial or there is exactly one positive real root. At $\tau = 0,\ h(\tau) < 0$ and at $\tau = 1,\ h(\tau) = 1 - 4\rho\eta < 0$, which implies that are no positive real roots of the polynomial and $h(\tau) < 0, \forall \tau \in [0,1]$.

Q.E.D.

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