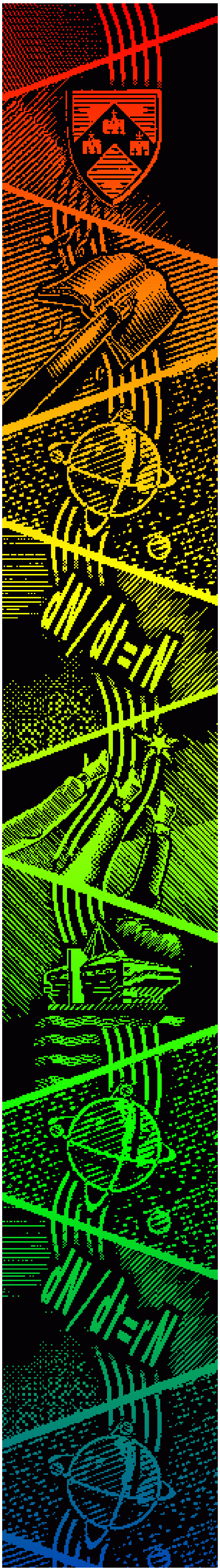

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Valuing Voluntary Disclosure using a Real Options Approach

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Valuing Voluntary Disclosure using a Real Options Approach*

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Abstract

This paper outlines a real options approach to valuing those announcements which are made by firms outside their legal requirements. From the firm's perspective, information is disclosed only if the manager of the firm is sufficiently certain that the market response to the announcement will have a positive impact on the value of the firm.

When debt financing is possible it is found that the manager adopts a more transparent disclosure policy, thus violating the Modigliani–Miller theorem on irrelevance of capital structure on firm value.

Keywords: Voluntary Disclosure, Real Options, Modigliani–Miller Theorem.

JEL Classification Numbers: C61, D81, M41.

1 Introduction

Corporate voluntary disclosure has become an important element of capital market dynamics (Wen [22]) in that it conveys value-relevant information for market pricing. As well as this, it typically contains information related to a firm's activities which may not be immediately stated in accounting reports. The issue has become increasingly topical and important in the aftermath of

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some major corporate scandals such as Enron, WorldCom and others. Such events have raised concerns over the transparency of U.S. firms and, in particular, the quality of their financial reporting and disclosures (Dempster [5]). This paper demonstrates how a real options approach to valuation can contribute to our understanding of corporate disclosure, and in particular, *voluntary* corporate disclosure which is concerned with those announcements willingly made by firms which are outside their legal and regulatory requirements.

One of the earliest findings in the disclosure literature, provided by Grossman and Hart [12] and Grossman [11], has become known as the "unravelling result". If the managers of firms, holding private information, choose not to disclose their information to outside investors, then the investors will discount the value of the firm down to the lowest possible value consistent with whatever voluntary disclosure is made. Once the managers realise this, they will have an incentive to make full disclosure. Dye [8], however, challenges this result, and provides a reasoning for why it may not always hold. He shows that the qualitative features of an optimal disclosure policy for management may take the form of a policy dependent cutoff in which management disclose only if the information is sufficiently good, otherwise they withhold disclosure. His reasoning is due to the uncertainty of investors about the firm's information endowment; that is, investors may not be able to distinguish between managers holding undisclosed information from managers being uninformed. In such a setting, investors seeing non-disclosure must temper their inferences concerning the likelihood of a manager having observed bad news and opting not to disclose by the fact that non-disclosure may have arisen due to managers being uninformed. Since these early seminal contributions by Grossman [11] and Dye [8], a large body of work has emerged on corporate voluntary disclosure. Verrecchia [21] provides an extensive survey on such disclosure models.

One interpretation of voluntary announcements is that they provide an opportunity for managers to communicate to the marketplace that they are aware of, and up to date with, current investor demands and interests. For example, Subramani and Walden [17], in their study of the market impact of e-commerce announcements, argue that the reason for the significant positive abnormal returns that they found were in part because investors viewed announcement of such initiatives as favourable signals of certain firm attributes. Furthermore, Graham et al. [10] argue that companies voluntarily disclose information to provide clarity to (potential) investors.

The role of disclosure has been recently investigated in the finance literature, which considers how a firm's disclosure policy may affect competition and/or highlight or amplify financial market inefficiencies (see Admati and Pfleiderer [1]). Their research shows that a firm's market value can be driven by investors' hopes and fears about, for example, growth opportunities as much as by any fundamental analysis. Thus, announcements may affect market perceptions about expected future earnings and risk.

Importantly, across various streams of research investigating corporate disclosure, there is a growing recognition that the various announcements that firms make have an inherent strategic value in their power to influence external perceptions directly and firm performance indirectly (see Bettis [3]).

In principle, a firm can make an announcement about anything it chooses, and thus, the range of announcement applications is endless. Examples of such announcements include competitive pricing strategies, new product introductions, various mergers, acquisitions and other alliances, and a range of detailed structural changes within the firm. However, in practice, firms tend to make announcements only about key strategic and organisational events that could impact substantially on their value and success (see Bayus et al. [2]).

In this paper we view voluntary disclosure of information relating to the state of the firm to the marketplace as a (real) option held by the the firm's manager. Exercising the option to disclose information is a strategic decision on the part of the firm, which implies that the manager will only do so if he is sufficiently certain that the payoffs are positive, i.e. that the option is deep enough in the money. In this paper we measure the payoff to the disclosure option by the impact of market response to the information on the value of the firm. This reflects the standard corporate practise to (partly) remunerate managers based on the firm's stock market performance. This, effectively, aligns the manager's incentives with potential sellers of the firm's equity. They, after all, are interested in firm value to be as high as possible.

We also adapt the model show to that it provides an example of a violation to the Modigliani–Miller theorem on irrelevance of financial structure on firm value. When, namely, some of the disclosure cost is financed with debt, the limited liability aspect of debt dominates the loss to the firm from compensating the lender for expected default losses, and consequently, the optimal disclosure threshold for the manager is lower. As such this is an interesting example where excess risk taking by managers due to limited liability protection of debt financing actually has a positive effect.

From a modelling point of view our paper is most closely related to Thijssen et al. [20] and Sabarwal [14]. The model of the arrival of imperfect signals over time follows that of Thijssen et al. [20]. That paper analyses the problem of a firm with the opportunity to invest in a project which has an uncertain profitability and, therefore, does not feature the debt financing issue that is central to our paper. Sabarwal [14] shows how the ideas regarding the value of the option to wait provide a violation of the Modigliani–Miller theorem, but he deals with uncertainty using the standard framework of real options literature (see Dixit and Pindyck [6]), whereas in our model, uncertainty is resolved over time and thus, standard stochastic calculus tools cannot be used.

The paper is organised as follows; the benchmark model is described and the optimal stopping problem for the disclosure threshold is solved in the next section. Section 3 discusses some of the important features inherent in the manager's optimal disclosure policy. Section 4 analyses the model from another dimension; namely if some of the disclosure cost is financed with debt, and Section 5 finally concludes. All proofs appear in the Appendix.

2 The Model

Consider a firm that has invested in a new project and that receives private information over time pertaining to the project's performance (like, for example, sales figures). We assume that the firm's management is not legally obliged to disclose this information. Thus, the manager can exercise discretion over whether to share his private information with the market or to withhold it. His objective is to adopt a disclosure policy such that his own current expected (discounted) utility from wealth is maximised.

It is assumed that the manager of the firm is uncertain about how the private information he holds will be perceived by the market. This source of uncertainty differs with Dye [8] in the sense that he assumes the uncertainty arises because the market is unsure what, if any, information the manager has obtained. Indeed, in the current set-up, this assumption of response uncertainty is necessary to prevent (extremely) high returns from being disclosed, an act that would initiate the unravelling process described by Grossman and Hart [12].

If the information is regarded positively by the market, we assume this will result in a change in the (present) value of the firm of $V^P > 0$ or, if regarded negatively, a change of $V^N < 0$. There are several reasons why such response uncertainty may arise. Firstly, a firm's manager has imperfect information about a shareholder's prior expectations, in which case the firm does not know whether the response to disclosure will be favourable or unfavourable. Secondly, the market can interpret the disclosed information in different ways. In Dutta and Trueman [7], response uncertainty arises because firms do not know how investors will interpret the firm's private information. They present the disclosure of order backlog as an example. Investors can interpret a high-order backlog favourably if they believe that it signals high demand for the firm's product. Alternatively, they can interpret a high-order backlog unfavourably if they believe that it signals problems with the firm's production facilities or a manager's lack of control over operations. Finally, as argued in Suijs [18], response uncertainty can arise if investor response also depends on other factors that are beyond the firm's control, such as disclosure by competitors.

It is further assumed that all disclosures are (ex post) verifiable; that is, a manager will not issue misleading information in an attempt to alter the market's perception of his firm's prospects. Stocken [16] examines in detail the credibility of a manager's disclosure of privately observed nonverifiable information. His main finding is that a manager will almost always endogenously truthfully disclose his private information because if the market perceives lack of credibility in the disclosure, it will ignore it and this can lead to deeper problems for the firm in the future. The credibility could also be interpreted from the manager's reputation perspective. According to a study conducted by Graham et al. [10], executives believe that a reputation for not consistently providing precise and accurate information can lead to the under-pricing of the firm's stock.

In this model, disclosure is costly and the sunk cost involved in disclosing the information signal(s) is denoted by $I > 0$, such that $V^N < 0 \leq I < V^P$. For example, there may be some direct costs associated with producing and disseminating information; that is, information may need to be disclosed or certified by third parties such as accounting firms. It is important to note that these costs are direct and do not relate to the (indirect) proprietary costs that are typically referred to in the disclosure literature such as the cost of revealing firm sensitive information to competitors. There also exists an exogenous opportunity cost of waiting for more, and possibly better, information signals to arrive. By waiting for further signals, the manager can be more certain of the overall value of the firm, which will reduce the likelihood of misinforming the market and thereby damaging his reputation. These costs of announcing the information, and therefore exercising the disclosure option, could greatly outweigh the benefit of disclosure.

We assume throughout that a fraction of the firm is owned by the manager. Therefore, the manager's compensation depends upon the firm's activities, and as such, he is compensated with a fraction of the option to disclose. Note that if the manager's compensation does not depend on the disclosure option itself, then in the absence of control, the manager should not have any preference for the timing of disclosure. Assuming that the manager's preferences are quasi-linear in his share in the firm's value we can assume the manager to maximise firm value.

Furthermore, it is assumed that the firm has invested in a project and receives (private) information regarding the project's profitability. The manager has, at any time, the option to voluntarily disclose the information at a sunk cost $I \geq 0$. The manager is uncertain about market reaction to the disclosure. The true state of the world can be either good ($\eta = 1$) or bad ($\eta = 0$) resulting in a change in firm value of $V^P > I$ or $V^N < 0$, respectively. Over time, the manager receives information, the arrival of which follow a Poisson process with parameter $\mu > 0$. Information is interpreted by the manager as either increasing the likelihood of a positive market response or decreasing it. Each batch of information, however, is an imperfect signal which reflects the true market reaction with probability $\theta \in (1/2, 1)$. In this set-up the number of signals indicating a positive market reaction net of the number of signals indicating a negative market reaction is a sufficient statistic for the manager's optimal disclosure policy. At time t this number of signals is denoted by $s_t \in \mathbb{Z}$. Under the assumptions regarding the arrival and precision of information it can be shown that s_t evolves over time according to (cf. Thijssen et al. [20])

$$ds_t = \begin{cases} 1 & \text{w.p. } [1_{(\eta=1)}\theta + 1_{(\eta=0)}(1-\theta)]\mu dt \\ 0 & \text{w.p. } 1 - \mu dt \\ -1 & \text{w.p. } [1_{(\eta=1)}(1-\theta) + 1_{(\eta=0)}\theta]\mu dt. \end{cases} \tag{1}$$

Suppose that the manager has a prior over the probability of a positive market reaction equal to $p_0 \in (0,1)$. If, at time $t \geq 0$, the manager observes s_t, then the his posterior probability of a favourable market response follows from an application of Bayes' rule (see Thijssen et al. [20]):

$$p_t := p(s_t) = \frac{\theta^{s_t}}{\theta^{s_t} + \zeta(1-\theta)^{s_t}}, \tag{2}$$

where $\zeta = (1-p_0)/p_0$ is the prior odds ratio. Note that p is a monotonically increasing function and that the inverse function is given by

$$s(p) = \frac{\log\left(\frac{1-p}{p}\right) - \log(\zeta)}{\log\left(\frac{1-\theta}{\theta}\right)}. \tag{3}$$

This implies that we can either work with the number of net signals or the posterior belief. In the following we use both approaches intermittently, depending on analytical convenience.

If the manager discloses the information at time $t \geq 0$, then, conditional on the prior p_0, the expected change in the firm's value equals

$$U(s_t) := p(s_t)V^P + (1 - p(s_t))V^N - I. \tag{4}$$

Assuming that the manager discounts future payoffs at a constant rate $r > 0$, his problem can be formulated as an optimal stopping problem,

$$U^*(s_t) = \sup_{\tau \geq t} \mathbb{E}_t\left[e^{-r\tau}U(s_\tau)\right], \tag{5}$$

where $\mathbb{E}_t$ denotes the expectation conditional on all information available up to and including time t, and the supremum is taken over stopping times.

Problem (5) has an analytical solution, which takes the form of a threshold policy: the manager should disclose the information as soon as the posterior belief exceeds a certain threshold belief p^*. Adapting the arguments in Thijssen et al. [20] to our setting this threshold can be shown to be given by (see Appendix A for details)

$$p^* = \frac{\theta - 1 + \beta_1}{1-\theta}\left[\frac{V^P - V^N}{V^N - I} - \frac{\beta_1}{\theta}\frac{(V^P - I)}{(V^N - I)} + \frac{\beta_1}{1-\theta}\right]^{-1}, \tag{6}$$

where $\beta_1 > \theta$ is the larger (real) root of the quadratic equation

$$\Psi(\beta) \equiv \beta^2 - \left(\frac{r}{\mu} + 1\right)\beta + \theta(1-\theta) = 0. \tag{7}$$

Note that there is no guarantee that there exists an integer $s \in \mathbb{Z}$ such that $p^* = p(s)$. In other words, the optimal disclosure threshold in terms of net signals can be any real number. Since signals are integers this implies that the manager should wait until the posterior probability, driven by (2) exceeds p^*. In other words, the disclosure threshold in terms of net signals is $s^* = \lceil s(p^*) \rceil$.[1]

3 Properties of the Optimal Disclosure Policy

This section provides an insight into the main features that emerge from the manager's disclosure policy. The following proposition shows that the policy under the current approach gives a more stringent criterion than the standard NPV approach demands. This is a standard result from the real options literature (see, for example, Dixit and Pindyck [6]) and arises from the fact that the traditional NPV approach does not incorporate the opportunity cost of waiting for more informative signals by exercising the option immediately. Its proof can be found in Appendix B.

Proposition 1. *The real options approach leads to a well-defined threshold probability, p^*, and requires a more stringent criteria on the timing of disclosure than the classical NPV approach would demand.*

The result of a comparative static analysis of the threshold, p^*, with respect to the model's key economic variables is given in the following proposition, the proof of which is obtained through simple calculus and is, therefore, omitted.

Proposition 2. *The threshold belief in a positive market response, p^*, increases with I, and decreases with V^P and V^N.*

The greater the impact an announcement will have on the positive value of the firm, that is, the higher V^P, the lower the threshold belief in a positive trading response needs to be before the manager exercises his option to disclose the information. Hence, the firm will announce its information to the market earlier. This is consistent with Suijs [18] who finds that a stronger positive response makes disclosure a more attractive option, and therefore, the firm can be less certain about the market reaction being positive for disclosure to be optimal.

Additionally, the lower the impact an announcement will have on a negative trading response, that is, the higher V^N, the earlier the firm will disclose. This

[1]For $s \in \mathbb{R}$, $\lceil s(p^*) \rceil := \min\{k \in \mathbb{Z}_+ | k \geq s\}$.

is again corroborated by Suijs [18] who points out that a stronger negative response makes disclosure less attractive compared to nondisclosure, and thus, the firm must be more certain about being a good firm for disclosure to be optimal.

The greater the cost of making an announcement, the higher the threshold belief in a positive response and the later the firm will announce. This is owing to the fact that if the (direct) costs of, say, preparing or disseminating information are high, the manager requires more time to confirm the accuracy of the information signals. By so doing, he obtains a stronger conviction about how the market will react to the news and the likelihood of making a wrong disclosure decision is reduced.

From Figures 1 and 2, we can see how p^* and s^*, respectively, change with θ. It is evident that the critical belief in a positive market response increases with the quality of the information signal, and indeed, comparative static results would support this. However, Figure 2 shows that the critical number of positive over negative signals, s^*, decreases in θ. Hence, the more informative the signal, the more attractive it is for the firm to wait and demand a higher certainty that disclosure will impact positively on the firm value, through the market response. However, this belief is reached after fewer signals have been obtained, i.e. when there is a lower excess of positive over negative signals. This result is explained by Sarkar [15]. When the quality of the signals are high (low), there are likely to be large upward (downward) jumps in the belief variable, p, and thus, the likelihood that the threshold, p^*, is attained after a lower number of positive over negative signals are obtained increases.

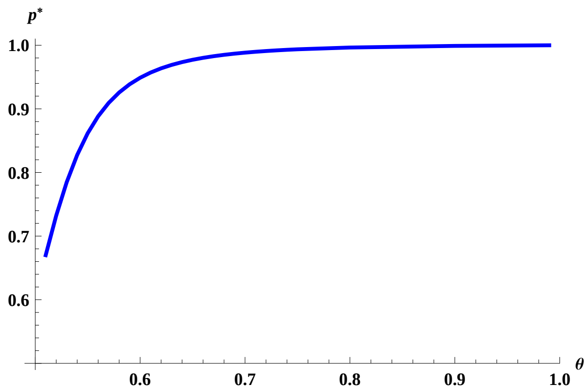

Figure 1: Comparative statics for p^* with respect to θ

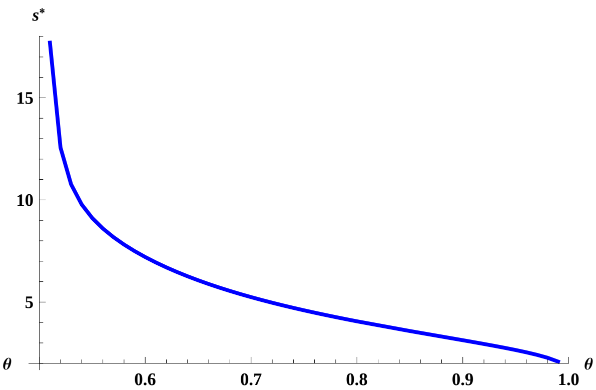

Figure 2: Comparative statics for s^* with respect to θ

Finally, we can say something about the frequency of information arriving on the optimal disclosure policy. The proof of the proposition below can be found in Appendix C.

Proposition 3. *As the expected time between signal arrivals increases, the manager's optimal disclosure threshold decreases.*

This proposition is consistent with Cosimano et al. [4] who find that over time, investor uncertainty is heightened when no voluntary disclosures have been made. Consequently, this increases the pressure for voluntary disclosure. A plausible explanation for this is given by Einhorn and Ziv [9] who examine corporate voluntary disclosures in a multi-period setting. They conclude that inter-temporal dynamics occur because a firm's use of their private information is assumed to be history dependent.

Now consider the situation where the true state of the world is a positive market response ($\eta = 1$). Using equation (21) in Thijssen et al. [20], which is the conditional first passage time density, we calculate the expected time until disclosure takes place as a function of μ. From Figure 3 it is clear that the function is not continuous and that the expected time of disclosure is not monotonic with respect to μ. This is because the realisations of s are discrete. Therefore, for certain values of μ, the threshold jumps from $\lceil s^* \rceil$ to $\lceil s^* \rceil + 1$. Since, from Proposition 3, p^* increases with μ, so too does s^*. If, as a result, $\lceil s^* \rceil$ increases with unity, one additional good signal (over the number of bad signals) is required before it is optimal to disclose the information. This implies that the expected time before disclosure jumps upwards. Immediately after the jump, the expected time decreases continuously with μ until the threshold jumps again.

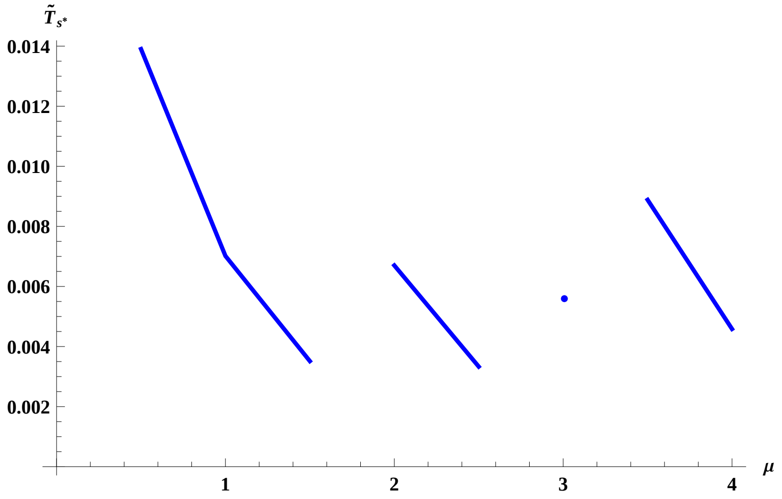

Figure 3: Comparative statics of expected time of disclosure given a positive response for μ with $\theta = 0.6$ fixed.

4 Debt and Voluntary Disclosure

In this section, we consider how the manager's disclosure policy is affected when some of the sunk costs associated with disclosure are financed with debt. As in Section 2, it is assumed that the manager is compensated via stock options and that he is given complete discretion about the disclosure policy he adopts.

Typically, it may not be realistic to assume that some of the disclosure costs are financed with debt since the relative magnitude of such costs are usually too small to warrant such an assumption. However, the disclosure aspect of whether to reveal the news about the project is still a contributor to the overall project's profitability through V^P, V^N, and I, and thus disclosure is simply an option problem within a bigger option problem which is beyond the scope of this section. If there is an injection of debt which generally funds the project's sunk costs, some of which are obviously made up of the sunk disclosure costs, then in that sense, debt is, at least partially, funding the disclosure. The idea for the coupon rate is similar; that is, part of the payoff from disclosure, if impact is V^P, is used to repay the debt via the coupon payment and if impact is V^N then none of the disclosure payoff goes toward the debt obligation.

The main reason for the association between debt and disclosure relates to the manager-lender conflict. Without debt, in an all equity firm, the manager incurs both upside and downside risk from making a disclosure. However, with debt, the manager's downside risk is limited, in that some of the sunk costs of disclosure are covered, and the lender is assumed to have first claim on revenues obtained from disclosure up to a fixed coupon, C, which the lender determines. This may provide the manager with *ex post* incentives to make decisions that are not in the lender's best interest. For example, the manager may opt to disclose some negative information about the prospects of the firm if he wishes to discourage other players from entering the market. Recognising this possibility, the lender demands a higher interest rate on the loan which implies a higher coupon payment.

The manager's objective is still to maximise his (discounted) expected utility from wealth, which is equivalent to maximising firm value owing to the compensation assumption, and the lender adopts a zero profit condition. The disclosure problem is then to determine an equilibrium belief level, p_d^{**}, such that, simultaneously, the manager's and the lender's objectives are satisfied, for a given level of debt. We also show how the disclosure policy changes as the debt level changes.

4.1 Manager's Problem

The manager gains when the firm's payoff from disclosure exceeds its debt obligation, and suffers a loss otherwise. However, he suffers far less damage if his payoff falls just short, or way short, of the debt obligation, than if all of the disclosure cost was financed with equity.

Denote by $0 < D \leq I$ the firm's only debt payment. It is assumed that if the response to disclosure is negative, and consequently, the impact on firm value is V^N, the firm defaults on its loan; that is, $V^N - (I - D) < 0$. In the event of a default, the payment to the lender is 0 and the manager suffers by the amount $V^N - (I - D) > V^N - I$. On the other hand, if the response is positive, the impact on firm value is V^P and it is assumed that the manager can meet his debt obligation. This implies that $V^P - (I - D) - C \geq 0$ and the lender is paid C while the manager retains the residual $V^P - I + D \geq 0$.

The expected change in value from disclosure at time t, conditional on p_0, is given by

$$\begin{aligned} U^D(s_t) =& p(s_t)(V^P - I + D - C) + (1 - p(s_t))(V^N - (I - D)) \\ =& p(s_t)(V^P - C) + (1 - p(s_t))V^N - (I - D), \end{aligned} \tag{8}$$

where $p(s_t)$ is given by equation (2).
Solving for the optimal threshold, via an optimal stopping approach (see Section 2 and Appendix A) yields the optimal threshold, when some of the cost is financed with debt, and this is given by

$$p_d^* = \frac{\frac{\beta_1+\theta-1}{1-\theta}}{\frac{V^P-C-V^N}{V^N-I+D} - \frac{\beta_1}{\theta}\left(\frac{V^P-C-(I-D)}{V^N-I+D}\right) + \frac{\beta_1}{1-\theta}} \tag{9}$$

which is a well-defined probability, if, and only if, $(I - D) \leq (V^P - C)$, which is satisfied.

4.2 Lender's Problem

In this subsection, we outline the problem from the lender's perspective. Similar to Sabarwal [14], we assume that the lender adopts a zero profit condition. Hence, he gets C with probability p_{l_t} and zero otherwise. Thus, his profit is given by

$$\pi_t^l = p_{l_t} C - D. \tag{10}$$

Note that p_{l_t} denotes the lender's belief, at time t, about the state of the firm. The lender acts to attain the zero profit condition implying

$$p_l^* = \frac{D}{C} \tag{11}$$

which is a well-defined probability if, and only if, $D \leq C$. This implies that he will only lend to the firm, to help them finance their disclosure policy, if he is sufficiently well compensated for the likelihood that the firm will default on its debt obligation if they adopt a very transparent disclosure policy; that is, he will only lend to the manager if he is prepared to pay a coupon which exceeds the amount of debt he is given. (Note that this same condition is necessary if, instead, the lender is assumed to adopt a profit maximising policy.)

4.3 Equilibrium

For a given level of debt, we want to find a coupon, C^*, such that $p_d^* = p_l^*$; that is, the manager's belief threshold about when to disclose is equal to the lender's belief threshold about when to lend. Equating equations (9) and (11) and solving for the coupon level C^*, we obtain

$$C^* = \frac{D\left(\frac{\beta_1}{1-\theta} + \frac{V^P - V^N}{V^N - I + D} - \frac{\beta_1}{\theta}\left(\frac{V^P - I + D}{V^N - I + D}\right)\right)}{\frac{\beta_1}{1-\theta} + \left(1 - \frac{\beta_1}{\theta}\right)\frac{D}{V^N - I + D} - 1} \tag{12}$$

implying that the equilibrium belief threshold for the manager, and indeed the lender, is given by

$$p_d^{**} = \frac{\frac{\beta_1 + \theta - 1}{1-\theta}}{\frac{V^P - C^* - V^N}{V^N - I + D} - \frac{\beta_1}{\theta}\left(\frac{V^P - C^* - (I - D)}{V^N - I + D}\right) + \frac{\beta_1}{1-\theta}}. \tag{13}$$

The main findings from an analysis of this equilibrium threshold are given in Proposition 4, Proposition 5, and Proposition 6 below. The proofs are outlined in Appendices D, E, and F, respectively.

Proposition 4. *The equilibrium belief, p_d^{**}, is a well-defined probability.*

Proposition 5. *The greater the level of debt obtained, the lower the threshold above which the manager will disclose, in equilibrium.*

This is owing to the fact that, with debt, the manager is likely to prefer a riskier and more transparent disclosure policy because his downside risk is limited; that is, the loss he may incur from a negative response reduces with the level of debt he obtains.

Proposition 6. *In equilibrium, the manager will disclose earlier, when some of the financing comes from debt, than if all of the disclosure was financed with equity; that is $p_d^{**} < p^*$.*

Firstly considering the manager's optimal disclosure policy, we have shown in Proposition 5 that to the extent that debt reduces the manager's disclosure cost, and that limited liability reduces his downside risk, the disclosure threshold is lower. However, on the other hand, to the extent that the lender anticipates the likelihood that the response to disclosure will be negative, and thus, the manager defaults on his debt, he demands a coupon that compensates him for this risk. As already pointed out, this coupon, or repayment, is actually larger than the amount of debt he lends. Thus, the manager's payoff from disclosure decreases in the coupon payment demanded, as does his belief threshold in equilibrium, p_d^{**}. Hence, the higher the coupon payment, the later the manager discloses as he requires greater conviction that a positive response will ensue. Overall, in equilibrium, we find, similar to Sabarwal [14], that the net effect of this type of debt-financing is negative; that is, the coupon payment demanded is not so high that the manager requires even greater conviction before disclosing that the response will be positive than if all his financing arose from equity. Hence, the reduction in the investment cost and the impact of limited liability appears to be sufficient in encouraging the manager to adopt a more transparent disclosure policy.

5 Conclusion

This research shows how adopting a real options approach can aid our understanding of corporate voluntary disclosure. The concept of a disclosure option is proposed and in this way the corporate disclosure literature is linked together with the real options literature. The decision to disclose, or withhold, information is strategic on the part of the firm. This implies that the manager will only announce the information if he is sufficiently certain that the market response to the information will have a positive impact on the value of the firm, and thus, on his own utility from wealth. An analytical expression for the manager's threshold belief in a positive market response to the disclosed information is derived and analysed using a real options framework. We show that the approach taken in this paper demands a higher threshold belief in a positive market response than under the classical NPV approach.

An extension to the model shows that the Modigliani–Miller theorem of investment financing is violated in the instance of corporate disclosure. When some of the disclosure cost is financed with debt, the manager adopts a lower disclosure threshold owing to the limited liability aspect of debt which dominates the loss incurred by the manager through compensating the lender for expected default losses.

To conclude, there are two points worth noting with regard to relevant issues which are absent in the analysis. The first is that the market for voluntary disclosure is assumed to be complete; that is, the payoff to the manager from making a disclosure voluntarily may be perfectly replicated through trading with existing marketed securities. However, this assumption is at odds with reality, and therefore, an examination of the same problem, but under the assumption of incomplete markets, could have an interesting effect on the current results. The problem in incomplete markets is that there is no unique way to value the option. A possible way forward here would be to adopt the approach taken in Thijssen [19]. He views market incompleteness as a case of ambiguity over the correct way to discount future payoffs. A multiple prior model together with the assumption of ambiguity aversion leads to a well-defined option value. In a standard real options setting Thijssen [19] shows that the effect of market incompleteness is not trivial. It is to be expected that similar results hold in the case of voluntary disclosure. The second aspect worth noting is that the manager does not face any competitive pressure whilst deciding on an optimal disclosure policy. Once again, this assumption is an abstraction from reality, the examination of which ought to be conducted in further research.

Appendix

A Derivation of the Optimal Disclosure Policy

The critical value of the conditional belief in a positive market response to an announcement, denoted $p^* = p(s^*)$, is the point such that the manager is indifferent between disclosing the information and withholding it. That is, if $p_t > p^*$, the manager is confident that there will be a positive trading response to the announcement if disclosed. On the other hand, if $p_t < p^*$, the manager is not confident enough in a positive response and waits for more information to arrive.

In order to solve for p^*, the approach taken is to solve the optimal stopping problem (5) by examining two scenarios. This solution approach is similar to the approach taken by Jensen [13] and Thijssen et al. [20]. The *stopping value*, denoted by $U(s)$ and given by (4), is the expected return to the firm from disclosing the information to the market immediately. This is the first scenario examined. The alternative scenario is that it is optimal not to disclose immediately, but to wait for more signals to arrive. The value of the option, known as the *continuation value*, denoted by $C(s)$, represents the discounted expected value of the next piece of information.

Since there are no cash-flows accruing from the disclosure option, $C(\cdot)$ should satisfy the Bellman equation over a small interval of time dt, i.e.

$$C(s_t) = e^{-rdt}\mathbb{E}_t[C(s_{t+dt})]. \tag{A.1}$$

This equation says that the value of the option at time t should equal its discounted expected value at time $t + dt$, where the time interval dt becomes infinitesimally small. In a small time interval dt, no information is received by the manager with probability, $1 - \mu dt$. On the other hand, information arrives with probability μdt. If information arrives, the value of the option jumps, either to $C(s_t + 1)$ if the information is deemed to signal a positive market reaction, or $C(s_t - 1)$ otherwise. Assuming that the current number of net signals is s (and, hence, that the current posterior belief in a positive market reaction is $p(s)$), this implies that (A.1) becomes

$$\begin{aligned} C(s) =&(1 - rdt)\Big\{(1 - \mu dt)C(s) + \mu dt\Big[p(s)[\theta C(s + 1) + (1 - \theta)C(s - 1)] \\ &+ (1 - p(s))[\theta C(s - 1) + (1 - \theta)C(s + 1)]\Big]\Big\} + o(dt). \end{aligned} \tag{A.2}$$

Substituting for $p(s)$ using (2), dividing by dt and taking the limit $dt \downarrow 0$, we obtain the following difference equation:

$$\hat{C}(s + 1) - \frac{r + \mu}{\mu}\hat{C}(s) + \theta(1 - \theta)\hat{C}(s - 1) = 0, \tag{A.3}$$

where

$$\hat{C}(s) := (\theta^s + \zeta(1 - \theta)^s)C(s),$$

Equation (A.3) has a general solution given by

$$\hat{C}(s) = A_1\beta_1^s + A_2\beta_2^s,$$

where A_1 and A_2 are constants and $0 < \beta_2 < 1 - \theta < \theta < \beta_1$ are the solutions to the fundamental quadratic (7). So, the value of the disclosure option equals

$$C(s) = \frac{A_1\beta_1^s + A_2\beta_2^s}{\theta^s + \zeta(1 - \theta)^s},$$

Imposing several boundary conditions then leads to a solution for the unknowns s^*, A_1, and A_2. First of all, if $s \to -\infty$, the probability of the posterior belief ever reaching p^* goes to zero and, hence, the option becomes worthless. So, it should hold that $\lim_{s\to-\infty} C(s) = 0$. Since $0 < \beta_2 < 1 - \theta$ this implies that $A_2 = 0$. A second condition is that the value of the option should be continuous at s^*. The third boundary condition is another continuity condition that stems from the realisation that the point $s^* - 1$ is special. In deriving $C(\cdot)$ it was (implicitly) assumed that after receiving the next signal disclosure still does not take place. But, for $s \in [s^* - 1, s^*)$, the manager knows that if the next signal indicates a positive market reaction, then disclosure should take place. Denoting the option value in the range $[s^* - 1, s^*)$ by CU, it can be shown to be given by

$$\begin{aligned} CU(s) =&\frac{\mu}{r + \mu}\Big\{[p(s)\theta + (1 - p(s))(1 - \theta)]U(s + 1) \\ &+ [(1 - p(s))\theta + (1 - \theta)p(s)]C(s - 1)\Big\}]. \end{aligned} \tag{A.4}$$

So, the value of the disclosure option is

$$U^*(s) = 1_{(s<s^*-1)}C(s) + 1_{(s^*-1\leq s<s^*)}CU(s) + 1_{(s\geq s^*)}U(s).$$

This is a *free-boundary problem*, for which the constant A_1 and threshold s^* can be found by the continuity conditions $C(s^*-1) = CU(s^*-1)$ and $CU(s^*) = U(s^*)$. Solving in terms of $p^* := p(s^*)$ gives

$$p^* = \frac{\theta - 1 + \beta_1}{1-\theta}\left[\frac{V^P - V^N}{V^N - I} - \frac{\beta_1}{\theta}\frac{V^P - I}{V^N - I} + \frac{\beta_1}{1-\theta}\right]^{-1}. \tag{A.5}$$

B Proof of Proposition 1

To prove that p^* is a well-defined probability, we need to establish that $0 < p^* \leq 1$. Firstly, $\beta_1 > 1-\theta$ ensures that the numerator of (6) is positive. Since, by assumption, $V^N < I \leq V^P$, p_{NPV} is a well-defined probability. This, added to the fact that $V^N < 0$, implies that the denominator is also positive and, hence, $p^* > 0$. Secondly, to ensure that $p^*_m \leq 1$, the inequality

$$\frac{-1}{p_{NPV}} - \frac{\beta_1}{\theta}\left(\frac{V^P - I}{V^N - I}\right) \geq -1,$$

must be satisfied. Substituting for p_{NPV} yields

$$V^P - \frac{\beta_1}{\theta}\left(V^P - I\right) \leq I,$$

implying that

$$\left(1 - \frac{\beta_1}{\theta}\right)V^P \leq (1 - \frac{\beta_1}{\theta})I.$$

This final inequality is satisfied since $V^P \geq I$ and $\beta_1 > \theta$.

Let p_{NPV} denote the disclosure threshold under the standard new present value criterion. Then p_{NPV} is such that at p_{NPV} the benefits from disclosure are exactly equal to the (sunk) costs incurred. So,

$$U(p_{NPV}) = 0 \Longleftrightarrow p_{NPV} = \frac{I - V^N}{V^P - V^N}.$$

Note that p^* can be written in terms of p_{NPV} as follows:

$$p^* = \frac{\beta_1 + \theta - 1}{1-\theta}\left[\frac{\beta_1}{1-\theta} - \frac{\beta_1}{\theta}\frac{V^P - I}{V^N - I} - \frac{1}{p_{NPV}}\right]^{-1}.$$

Some trivial algebraic manipulation shows that

$$p^* > p_{NPV} \Longleftrightarrow \frac{1}{\theta} - \frac{1}{1-\theta} < 0.$$

This inequality is satisfied since, by assumption, $\theta > \frac{1}{2}$. ∎

C Proof of Proposition 3

The expected time between the arrival of two signals is $\frac{1}{\mu}$ (Dixit and Pindyck [6]). p^* denotes the manager's disclosure threshold. Taking implicit derivatives shows that p^* decreases in $\frac{1}{\mu}$:

β_1 is given by

$$\beta_1 = \frac{r+\mu}{2\mu} + \frac{1}{2}\sqrt{\left(\frac{r}{\mu}+1\right)^2 - 4\theta\,(1-\theta)}$$

and comparative statics show that it is decreasing in μ; i.e.

$$\frac{\partial \beta_1}{\partial \mu} < 0.$$

p^* is given by equation (6), and a comparative static result on p^* with respect to β_1, yields the following condition:

$$\frac{\partial p^*}{\partial \beta_1} < 0 \Longleftrightarrow \frac{2\theta - 1}{\theta}\left(V^P - I\right) > 0.$$

Since $V^P > I$ and $\theta > \frac{1}{2}$, by assumption, p^* decreases in β_1.

Therefore,

$$\frac{\partial p^*}{\partial \mu} = \frac{\partial p^*}{\partial \beta_1}\frac{\partial \beta_1}{\partial \mu} > 0$$

and hence, p^* decreases in $\frac{1}{\mu}$. ■

D Proof of Proposition 4

It is easily established that p_d^{**}, given by equation (13), is well-defined if, and only if, $C^* \leq V^P - I + D$, where C^* is given by equation (12).
This condition is adhered to when

$$D\left(\frac{\frac{\beta_1}{1-\theta}\left(V^N - I + D\right) + V^P - V^N - \frac{\beta_1}{\theta}\left(V^P - I + D\right)}{\frac{\beta_1}{1-\theta}\left(V^N - I + D\right) + I - V^N - \frac{\beta_1}{\theta}D}\right) \leq V^P - I + D. \quad \text{(D.1)}$$

Algebraic manipulation reduces the expression (D.1) and $C^* \leq V^P - I + D$ holds once

$$\left(\frac{\beta_1}{1-\theta} - 1\right)\left(V^N - I + D\right) \leq 0.$$

This is satisfied since $\beta_1 > \theta > \frac{1}{2}$, implying $\beta_1 > 1 - \theta$, and $V^N - I + D < 0$, by assumption. ■

E Proof of Proposition 5

Substituting for C^* in equation (9) using (12), and taking comparative statics with respect to D, we find that the equilibrium belief threshold decreases with increasing levels of debt if, and only if

$$\begin{aligned}&\beta_1\left(V^P-(I-D)\right)\left(\frac{1}{1-\theta}-\frac{1}{\theta}\right)+\\&\frac{D}{V^N-(I-D)}\left(V^P-V^N\right)\left(1-\frac{\beta_1}{\theta}\right)>0.\end{aligned} \tag{E.1}$$

Since $\theta > \frac{1}{2}$, by assumption, $\frac{1}{1-\theta} - \frac{1}{\theta} > 0$ and $\beta_1 > \theta$ implying that $1 - \frac{\beta_1}{\theta} < 0$. Hence the condition given by (E.1) holds, and p_d^{**} is decreasing in debt. ■

F Proof of Proposition 6

$p_d^{**} < p^*$ if, and only if,

$$\frac{I-V^N}{V^P-V^N} < \frac{D}{C^*}, \tag{F.1}$$

where C^* is given by equation (12).
After substituting for C^*, an algebraic manipulation reduces this expression to the condition that (F.1) holds if

$$\left(\frac{1}{\theta}-\frac{1}{1-\theta}\right)\left(V^P-I\right)\left(V^N-I+D\right)>0$$

However, since $\theta > \frac{1}{2}$, by assumption, $\left(\frac{1}{\theta} - \frac{1}{1-\theta}\right) < 0$. Moreover, $V^P \geq I$ and $(V^N - I + D) < 0$ which implies that the expression is positive, and that the condition given by (F.1) holds. Thus, $p_d^{**} < p^*$. ■

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