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Corporate Risk Management, Product Market Competition, and Disclosure*

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Abstract

This paper studies the effects of hedge disclosure requirements on corporate risk management and product market competition. The analysis is based on a model of market entry and shows that to prevent entry incumbent firms engage in risk management when these activities remain unobserved by outsiders. In the resulting equilibrium, financial markets are well informed and entry is efficient. However, potential attempts for more transparency by additional disclosure requirements introduce a commitment device that provides incumbents with incentives to distort risk management activities thereby influencing entrant beliefs. In equilibrium, firms engage in significant risk-taking. This behavior limits entry and adversely affects the nature of competition in industries.

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1 Introduction

"The fallacy that disclosure costs nothing has long been implicit in SEC rules. ... The more-is-always-better view fails to recognize that disclosing a risk often changes the risk itself. Disclosure inevitably affects behavior, not necessarily in socially desirable ways."

Merton Miller and Christopher Culp, WSJ (June 25, 1996); in a comment on SEC plans to mandate disclosures on how companies manage their risks

For the last two decades, standard setters put considerable efforts in mandating public firms to disclose key information about their risk management practices. In the United States, the FASB has issued major standards on accounting for hedge transactions, most notably SFAS No. 133 (1998), the Statement of Financial Accounting Standards on Accounting for Derivative Instruments and Hedging Activities. In recent years, this standard has been amended multiple times.[1] In addition, the SEC requires public companies to disclose information about risk; the Financial Reporting Release No. 48 (1997) mandates firms to report forward-looking numerical measures of their market risk exposures related to financial instruments and derivatives. Regulators most likely proceed on this course to further improve transparency on firms' risk management activities.[2]

Despite these policy efforts, the literature on the effects of alternative hedge disclosures has so far remained relatively limited. DeMarzo and Duffie (1995) examine how alternate hedge accounting standards can lead to hedge distortions due to managerial labor market frictions. Likewise, Kanodia et al. (2000), Sapra (2002) or Hughes, Kao, and Williams (2002) study how hedge accounting standards affect both risk management and production policies. Our study adds to this literature that explores the real effects of hedge disclosure requirements. We depart from prior research, however, in examining alternative hedge disclosure requirements in a competitive setting of potential market entry. Such threats of market entry by rivals constitute a central

[1] Such amendments are SFAS No. 138 (2000), SFAS No. 149 (2003), SFAS No. 155 (2006), or SFAS No. 159 (2008). Likewise, the IASB has required firms to report hedge disclosures under IAS 39 since 2001 and just recently introduced IFRS 9 (2014).

[2] For a comprehensive guide on all the aforementioned standards and their evolution, see Ryan (2007) and Ryan (2012). In the appendix, we present a summary of the institutional background and current accounting standards.

theme in the theory of competition and are an important characteristic of most industries (see Dixit, 1980; Milgrom and Roberts, 1982; Fudenberg and Tirole, 1984). Entry is also widely recognized as one major driver of economic growth.[3] Our results indicate that disclosure of a firm's risk position can have unintended and undesirable implications for hedging incentives, industry structures, and overall social welfare.[4]

Our model is a learning model related in spirit to Holmström (1982), Fudenberg and Tirole (1986), Scharfstein and Stein (1990), and others. We focus on a stylized market structure with an incumbent and a potential entrant. The entrant is uncertain of its future profitability in the market and uses the persistent component of current profits of the incumbent to decide whether to enter. The established firm can engage in risk management, which reduces the noisiness of corporate earnings as a signal of market profitability and thus improves their informativeness. Less hedging, by contrast, lowers the informativeness of earnings, thereby allowing the incumbent to withhold information that could competitively disadvantage the firm. While one could conjecture that in the face of entry, the incumbent hedges less to interfere with any information transmission to the rival, our findings suggest that this is frequently not the case. If risk management is unobservable, the incumbent has strong incentives to engage in hedging under quite general conditions. Because entrants may interpret high profits as favorable market conditions, incumbent firms are trapped into risk management activities. They seek to minimize the variance of realized profits to minimize the probability of entry. Potential market entry hence creates strong forces to reduce risk. The resulting equilibrium is also socially desirable: the financial market is well informed about product market profitability and entry is efficient. This finding contrasts pronouncedly with equilibrium results in a regime with observable risk management activities. Then, the incumbent discloses its exposure which reveals additional information that an entrant may exploit. At the same time, the observability of risk management activities provides the incumbent with a strategic device to credibly communicate the absence of information contained in its financial reports when less hedging lowers the informativeness of earnings. We show that the incumbent indeed uses this commitment device and jams the signal sent to potential entrants by engaging in risk-taking to discourage entry. This obfuscation strategy reduces the probability of entry, increases incumbent profits, and decreases social welfare.

In the main part of our analysis, we consider two polar regimes to portray the consequences of disclosure: (i) a regime of non-observability in which firms cannot disclose risk management activities, and (ii) a regime of

[3]Entry affects levels of competition, resource allocation, and production efficiency in markets and facilitates innovation and change (see Geroski, 1989 or Aghion et al., 2009, as well the literature reviews in Siegfried and Evans, 1994 or Geroski, 1995).

[4]We will use the terms "hedging" and "risk management" interchangeably throughout.

perfect observability in which firms are mandated to disclose. In the extensions, we examine the role of voluntary disclosure of a firm's risk management activities (see section 4.4). We show that equilibrium outcomes in the mandated regimes studied encompass outcomes under relevant forms of voluntary risk management disclosure.

Despite the complexity of risk management activities by firms and the costs imposed for the economy by such regulations, standard setters move increasingly toward further disclosure to service the information needs of capital markets. We define as additional disclosure requirements any type of regulation that improves the information about a firm's risk management activities revealed by financial statements. In studying the admittedly extreme case of perfect observability of hedging activity, we examine consequences of additional mandated hedge disclosures, which a policy-maker may enforce in an attempt for greater transparency. Such mandated requirements could create negative externalities in the product market beyond any cost imposed by the mandatory regime per se. Standard setters might factor such externalities in when they move along the continuum of more transparent disclosure regulation.

Our results also add to recent studies on corporate hedging and the strategic interactions of firms in the product market (Mello and Ruckes, 2005; Adam, Dasgupta, and Titman, 2007; Loss, 2012; Disatnik, Duchin, and Schmidt, 2013). When risk management activities are unobserved by outsiders, latent competition by potential market entrants can create hedging incentives, even if firms are risk-neutral.[5] These hedging incentives tend to disappear under more transparent disclosure regimes. In this regard, we also contribute to the corporate risk management literature by providing a novel explanation for why firms may wish to engage in risk management. Finally, while this paper is designed to specifically illustrate that hedge disclosures may distort corporate risk management, it can be viewed more broadly as an attempt to shed light on the interaction between disclosure regulation and corporate financial policy. These interactions are subject of a growing literature that examines the effects of accounting rules on investment policies and capital structure (e.g., Göx and Wagenhofer, 2009; Bertomeu, Beyer, and Dye, 2011; Otto and Volpin, 2015; or Ellul et al., 2015).

We develop our arguments further in the following four sections. In section 2, we elaborate on related literature. In section 3, we present the structure and the assumptions of the model. In section 4, we analyze equilibrium strategies under non-observability and observability of hedging activities. Furthermore,

[5]It is well recognized that firms have strong incentives to engage in corporate risk management in the presence of market imperfections (e.g., convex tax schedules, deadweight cost of financial distress, or costs of external financing; see Smith and Stulz, 1985; Stulz, 1990; Froot, Scharfstein, and Stein, 1993). These models typically analyze the firm in isolation.

we present the model's empirical implications, relate the model to existing evidence, and provide extensions. Section 5 contains concluding remarks.

2 Related Literature

Our paper is related to several large strands of research in finance and accounting.

Literature on Hedge Disclosure. DeMarzo and Duffie (1995) analyze a model of risk management where corporate profits serve as a signal of a manager's ability. They demonstrate that with nondisclosure of hedging activity, full hedging is an equilibrium policy for managers. If hedge decisions are disclosed, however, managers have an incentive to forego risk management opportunities to render inference about their ability difficult for outside investors. Kanodia et al. (2000) investigate the desirability of hedge disclosures and their informational effect on futures prices. They show that disclosure of hedge activities improves price efficiency in the futures market and industry output. Sapra (2002) studies hedge disclosures with a focus on the trade-offs between production and risk management distortions. He finds that mandatory hedge disclosure drives a firm to take extreme positions in the futures market. We follow these papers in evaluating risk management decisions under a mandatory hedge disclosure regime relative to the benchmark situation in which firms cannot disclose their risk management activities. None of these papers considers product-market competition.

Literature on Risk Management and (Post-entry) Competition. Liu and Parlour (2009), Adam, Dasgupta, and Titman (2007), Mello and Ruckes (2005), and Loss (2012) study the relationship between risk management and competition. Liu and Parlour (2009) consider the interaction between hedging and bidding in a winner-takes-all auction context in which hedging renders winning more valuable and losing more costly. They find that the ability to hedge with financial instruments makes firms bid more aggressively because of running the risk of overhedging if they lose. Adam, Dasgupta, and Titman (2007) investigate firms' risk management choices in an industry equilibrium in which endogenous output prices are a function of aggregate investment and hedging decisions. They illustrate that a single firm's incentive to hedge increases if more firms in the industry choose not to hedge and vice versa. They also relate industry characteristics to the proportion of firms that hedge. Mello and Ruckes (2005) study optimal hedging and production strategies of financially constrained firms in imperfectly competitive markets. They find that oligopolistic firms hedge the least when they face intense competition and firms' financial conditions are similar. Likewise, Loss (2012) examines risk management of competing firms facing credit constraints. He shows that firms' hedging incentives depend on the correlation between the competitors' available internal funds to make profitable investments and on whether competitors' investments mutually reinforce or mutually offset investment returns. The reason is that hedging can ensure that firms optimally coordinate profitable investments and financing policies. This literature implicitly assumes that firms' risk management activities are typically non-observable. None of these papers studies the informational effects of additional hedge disclosures on risk management activities of competing firms.

Literature on Risk Management, Hedge Disclosure, and (Post-entry) Competition. Only few studies (Allaz, 1992; Hughes and Kao, 1997; Hughes, Kao, and Williams, 2002; Hughes and Williams, 2008) consider the effects of disclosure of hedging activities on product market competition.[6] Like our study, these works consider mandated hedge disclosure and non-disclosure regimes. While the welfare implications of these studies (e.g., industry output) are not clear-cut, they tend to favor the postulate that hedge disclosure is pro-competitive and thus welfare-improving (Hughes and Williams, 2008). However, these papers (like the works cited in the previous paragraph) examine situations in which firms face *post*-entry competition by looking at how hedge disclosure affects production output decisions of Cournot duopolists. By contrast, our study investigates *pre*-entry competition showing that disclosure deters market entry and can thereby reduce social welfare at the expense of the prospective entrant and consumers.[7] One particularity of pre-entry competition is that any disclosure regulation applies only to incumbents but not to prospective entrants.

[6]Prior studies on disclosure in the context of competition primarily focus on the role of private information about demand and cost and its revelation among competitors (e.g., Wagenhofer, 1990; Darrough, 1993, among others).

[7]In this regard, our paper is related to research studying industry externalities of disclosure on market entry (Darrough and Stoughton, 1990; Feltam and Xie, 1992; Feltham, Gigler, and Hughes, 1992; Hwang and Kirby, 2000; Schneider and Scholze, 2015). For instance, Hwang and Kirby (2000) study mandatory disclosure of firm-specific cost information and the effect on an incumbent's production quantity in a Cournot oligopoly if entry occurs.

3 The Model

3.1 Overview

We model a non-cooperative game among the established firm (or *incumbent*) I and the market entrant (or *rival*) R. The model consists of two periods, $t = 1, 2$. In the first period, the incumbent operates as a monopolist. The entrant observes the incumbent's first-period earnings and uses these to decide whether to enter the market in the second period. Firms are risk-neutral, and discount rates are zero.

3.2 Payoffs

The realization of first-period earnings of the incumbent is publicly observable. We assume these earnings y_1 are uncertain and given by

$$y_1 = \eta + \epsilon, \tag{1}$$

where η denotes the quality of the market and ϵ a stochastic noise term. Nature chooses η from a normal distribution with mean $\bar{\eta} > 0$ and variance σ_η^2. The pre-entry earnings are also exposed to the stochastic component ϵ, which can be interpreted as the firm's aggregated transitory exposure. It is independently distributed from η and also drawn from a normal distribution with variance σ_ϵ^2. We set its mean to zero for convenience. ϵ may incorporate both market-wide uncertainty, such as fluctuations in commodity prices, as well as firm-specific uncertainty, such as effects of shorter or longer-than-average machine stoppages during production. The prior distributions over η and ϵ are common knowledge. Neither η nor ϵ are directly observed, and they are unknown to the entrant. Market quality η is persistent in both periods.[8]

The incumbent may engage in hedging transactions that allow for controlling the distribution of ϵ. Specifically, we adopt a variant of DeMarzo and Duffie's (1995) characterization of hedging activity by assuming that the variance of ϵ is linear in the level of hedging $h \in [0, 1]$ and given by $(1-h)\sigma_\epsilon^2$. Thus, $h = 0$ if the incumbent does not engage in hedging, and $h = 1$ if the incumbent fully hedges. As a consequence, the resulting distribution of y_1 given the *prior estimate* of the market quality η is normal with mean $\bar{\eta}$ and variance $\sigma_y^2 := \sigma_\eta^2 + (1-h)\sigma_\epsilon^2$. We follow the literature (e.g., Froot, Scharfstein, and Stein, 1993) in assuming that hedging is costless and has no effect on the expected level of y_1. Corporate hedging is not limited to a risk

[8] Using these distributional assumptions enhances the tractability of our results. The posterior will also be distributed normally, and parameters can be updated by simple rules well-known from the literature on "conjugate priors."

transfer with marketable securities. Operational activities or insurance contracts may also provide effective risk management to reduce the incumbent's exposure.

In the second period, earnings of both firms are given by

$$y_{i,2} = (1 - \delta_i)\eta, \tag{2}$$

where $i \in \{I, R\}$ and $\delta_i \in (0, 1)$ parameterizes the duopoly profit from post-entry competition if entry has occurred.[9] The case of the incumbent enjoying a monopoly position in the second period is normalized to $\delta_I = 0$ and $\delta_R = 1$.

Our formulation of pre- and post-entry earnings in (1) and (2) is worth exploring in more detail. First, profits are serially correlated. High first-period earnings of the incumbent therefore provide favorable news about second-period profitability. Second, earnings of both firms are positively correlated and move in the same direction given a change in the market quality η. Taken together, these characteristics capture the notion that high profits of an established firm lead potential entrants to believe their own future profits are likely to be high as well. This raises the probability of entry by other firms.[10] Hence, in our formulation, η can be interpreted as a permanent and common measure of market profitability that similarly affects firm performance across the industry – factors such as the size of the market, the responsiveness of demand to changes in product prices, the firms' access to distribution channels, product differentiation over substitute products, or bargaining power over customers.

The formulation in (2) also abstracts from the incumbent's exit from the industry after the first period. Although using the normality assumption for the distribution of market quality is convenient for ease of exposition, non-positive profits are possible such that exit may be optimal if exit barriers are absent. For the sake of technical convenience, we follow convention in the literature (e.g., Vives, 1984, Gal-Or, 1985, Darrough, 1993) and ignore this possibility by assuming small variance of market quality relative to its mean.

[9] The parameter δ_i captures effects from duopoly competition that remain unspecified in our reduced-form model. These effects are well-known from the literature on industrial organization. First, if entry occurs, the entrant takes market share away from the incumbent. Second, entry intensifies price competition, as more firms imply lower prices. The magnitude of these effects may vary with the type of competition (quantity vs. price), the degree of product differentiation (homogeneous vs. heterogeneous), as well as demand and cost conditions. For reference, see Tirole (1988). Our results do not depend on particular parameter choices of δ_i.

[10] There is strong empirical support that high historical profits are positively related to market entry. We refer to surveys by Siegfried and Evans (1994) and Geroski (1995).

Then, such an event becomes unlikely. Concretely,

$$\bar{\eta} > \sigma_\eta. \tag{3}$$

3.3 Information Structure

We make two informational assumptions.

First, although first-period earnings of the incumbent are publicly observable, the realization of the firm's aggregated exposure ϵ is not. In this regard, thinking of ϵ as an unspecified function of both the numerous risks to which a firm is exposed and the firm's sensitivity to changes in these risks is useful. As a consequence, even if the hedging choice of the incumbent were observable, the entrant could not distinguish whether profits are high due to favorable market conditions or due to positive realizations of ϵ.

Second, we assume that neither firm knows the quality of the market. Hence, the incumbent and the entrant share the prior distribution of the market quality while making their decisions. Therefore, our model is not a signaling model. In particular, the incumbent may not strategically exploit an informational advantage. Industries are frequently subject to random shocks that factors such as general economy, technological innovations, or regulation can cause. After such shocks, uncertainty about the quality of a market will likely remain similarly unresolved for both firms. Although we recognize that firms attempt to acquire information about the realization of these shocks and may also possess access to superior information, we abstract from these considerations in order to isolate the effects of hedging. Symmetric information about the quality of the market enables a clear-cut analysis without adding another effect from private information.

We summarize the sequence of actions and events in Figure 1.

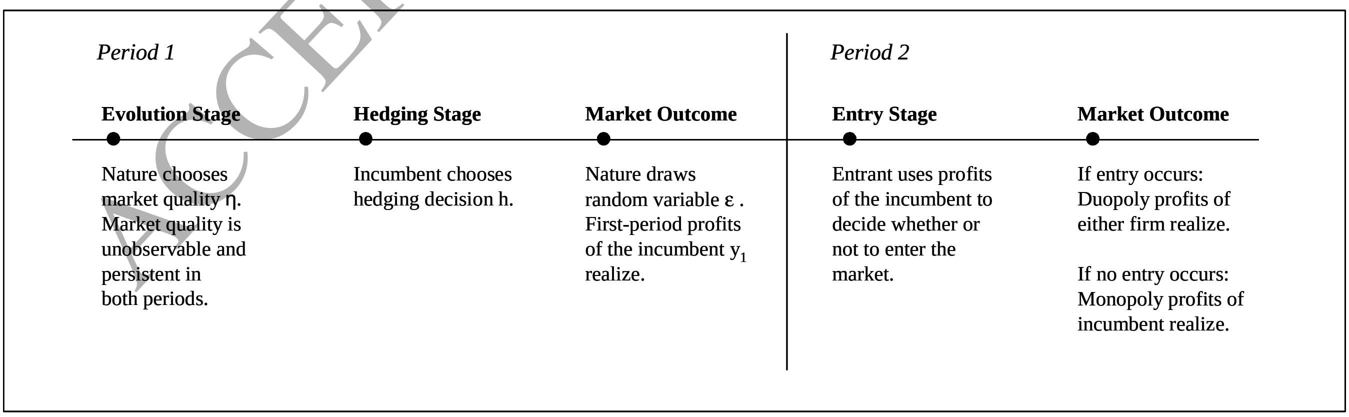

Figure 1: Sequence of actions and events

4 Analysis

In the next sections, we examine equilibrium strategies for two informational regimes: (i) a regime in which risk management activity is not observable; (ii) a regime where risk management activity is being fully revealed. In order to simplify the exposition, we focus on the derivation of pure strategy equilibria in the following section. Pure strategy equilibria exist for a wide range of parameter values and, as it turns out, mixed strategy equilibria only exist for parameter configurations for which pure strategy equilibria do not. For those parameters, we characterize the mixed strategy equilibria below.

4.1 Risk Management and Market Entry when Hedging Choice is Not Observable

If hedging activity of the incumbent is non-observable, the entrant may condition its belief about the quality of the market only on the observed profits of the incumbent and not on whether the incumbent hedges or not. Then, given the informational assumptions made above, even though the game has a sequential structure, we can solve it "as if" the two firms' choices were simultaneous. Each firm formulates and responds to a belief about what the other firm's actual choice is. As a consequence, to solve for equilibrium, we can proceed as follows. We begin with the analysis of entry conditional on a particular belief of the entrant about the incumbent's action. Conditional on this conjecture, we can solve for endogenous entry thresholds as a function of observed profits. Then, we investigate the incumbent's optimal hedging strategy and ask which strategy is preferred given a particular conjecture of the entrant. In equilibrium, the incumbent's optimal strategy and the entrant's conjecture converge.

4.1.1 Updating and Entry Strategies

Let market entry incur sunk costs to the entrant of K. The entrant chooses to enter if entry costs are less than expected post-entry profits. We assume that the entrant's ex-ante perception of post-entry profitability relative to its costs of entry is too low to justify entry,

$$(1 - \delta_R)\bar{\eta} < K \,. \tag{4}$$

In consequence, the entrant requires a positive piece of information from the first-period product market outcome in order to enter the market. If (4) did not hold, the entrant would have had an incentive to enter the market already in period 1. The entry cost K may represent investments in production capacity or marketing start-up costs. K is also any other type of measure to overcome barriers to entry that the incumbent is likely to erect. Such costs are well known and may result, for example, from reputational effects and marketing advantages of incumbency (Bain, 1956) or from exclusive contracts between buyers and the incumbent seller (Aghion and Bolton, 1987). However, at the end of period 1, new payoff-relevant information to the entrant arrives. The entrant observes the first-period profits y_1 of the incumbent. Since distributions of η and ϵ are common knowledge, the entrant can draw inferences from y_1. Conditional on the conjecture about the unobservable hedging choice of the incumbent, the entrant updates prior beliefs about market quality η according to Bayes' rule.

Pure strategies. We first describe the entrant's learning about the market quality η for a pure strategy of the incumbent, i.e. the situation in which the incumbent chooses one hedging level with probability one. Concretely, following the observation of y_1 and given a conjecture about the hedging choice of the incumbent, h^*, posterior mean and variance of η are

$$\bar{\eta}' = E(\eta \mid y_1, h^*) = \alpha y_1 + (1-\alpha)\bar{\eta} \tag{5}$$

and

$$\sigma_\eta^{2\prime} = \sigma_\eta^2(1-\alpha), \tag{6}$$

where

$$\alpha := \frac{\sigma_\eta^2}{\sigma_\eta^2 + (1-h^*)\sigma_\epsilon^2} \; . \tag{7}$$

The mode of Bayesian learning considered here is well known from, e.g., DeGroot (1970, p. 167) and Cyert and DeGroot (1974) and follows from the normality and independency of η and ϵ. Note that the posterior distribution of η is also normal. Equations (5) to (7) have natural interpretations. First, from equation (5), the revised mean $\bar{\eta}'$ is a weighted average of the observed profit y_1 and the unconditional mean $\bar{\eta}$. Hence, observing a *higher-than-expected* first-period profit of the incumbent, $y_1 > \bar{\eta}$, lifts the prior mean upward since strong profits of the incumbent are more likely for a high η and vice versa. Second, from equations (6) and (7), $\sigma_\eta^{2\prime} < \sigma_\eta^2$: the entrant has a more precise (i.e., higher quality) estimate of the market than it had ex-ante. In the extreme case, when the incumbent fully hedges, $\sigma_\eta^{2\prime}$ equals zero. Third, posterior estimates put more weight on signal y_1 if α is large. In fact, α strictly increases in h and decreases in σ_ϵ^2. The intuition is straightforward. The more a firm hedges (a high h) and the lower the initial variance of the noise term σ_ϵ^2, the more informative realized profits are about the quality of the market relative to the initial estimate. Hence, the entrant attributes a strong first-period result rather to favorable market quality than to good luck. The consequence is a significant revision of the prior.

We are now in a position to establish an entry rule for the entrant. Given a conjecture h^* about the unobservable hedging choice of the incumbent, entry occurs if (and only if) expected post-entry profits exceed the cost of entry

$$(1-\delta_R)E(\eta \mid y_1, h^*) > K,$$

which, by using (5), implies entry if y_1 satisfies

$$y_1 > \beta + \gamma(1-h^*) =: y^*, \tag{8}$$

where

$$\beta := \frac{K}{1-\delta_R} \text{ and } \gamma := \frac{\sigma_\epsilon^2}{\sigma_\eta^2}\left(\frac{K}{1-\delta_R} - \bar{\eta}\right).$$

The value y^* denotes the first-period profit of the incumbent above which the entrant chooses to enter the market. (We ignore the knife-edge case of $y_1 = y^*$.) Thus, the entrant's best reply to a pure strategy of the incumbent is a "threshold strategy".

A number of interesting properties are associated with the entry threshold y^* given by (8). These characteristics are corollaries of the properties of conditions (5) to (7). Using (4) implies $\gamma > 0$; hence, $y^* > \bar{\eta}$. In addition, more hedging strictly decreases y^*. The reason is straightforward. If the incumbent engages in more hedging activities, first-period profits become less noisy and reveal more about the true value of η and hence the expected post-entry profitability of the entrant. As a result, realized profits must rise less sharply above the prior mean to trigger entry. In contrast, increases in entry costs K and increases in the entrant's rent δ_R negatively affect post-entry profitability of the entrant, which in turn raises y^*. The opposite is true for the prior mean $\bar{\eta}$.

Mixed Strategies. The notion of a threshold strategy of the entrant extends to mixed strategies of the incumbent, that is, if the entrant conjectures that the incumbent mixes its pure strategies $h^* \in [0,1]$ according to a probability distribution. The entrant's expected post-entry profit to a (conjectured) profile of mixed strategies (after observing y_1) is given by the expected value of the corresponding pure-strategy payoffs,

$$(1-\delta_R)\int_0^1 E(\eta \mid y_1, h^*) g(h^*)\, dh^*, \tag{9}$$

where $g(h^*)$ is the density of the probability distribution characterizing the mixed strategy of the incumbent. From (5), the expected post-entry profit to the entrant in (9) is strictly increasing in y_1 for any mixed strategy of the incumbent. Equating (9) with entry cost K and solving for y_1 yields the unique threshold value y^*. We summarize the optimal behavior of the entrant in the following lemma.

Lemma 1 *Any equilibrium strategy of the entrant is a threshold strategy. Entry occurs if (and only if) first-period profits y_1 exceed a threshold value y^*.*

Lemma 1 implies that the entrant follows a pure strategy of either entering with probability one or refraining from doing so depending on the realization of the first-period profit of the incumbent.

4.1.2 Hedging Strategies and Equilibrium

Pure and Mixed Strategies. We are now ready to analyze equilibrium strategies using the findings in the previous section. Taking into account that any equilibrium strategy of the entrant is a threshold strategy, we begin with solving for the incumbent's best response (in pure and mixed strategies) conditional on a conjecture about the entrant's threshold value y^*. If the incumbent's best response is a unique hedging level, the hedging strategy is pure. Otherwise, the best response of the incumbent includes mixed strategies, that is, randomizations between hedging levels that all yield the same payoff to the incumbent.

The incumbent chooses h^* to maximize the expected profits given its belief about the entrant's threshold value y^*. Although the hedging choice of the incumbent influences the variance of first-period profits y_1 and the information about η that first-period profits y_1 contain, hedging does not affect expected first-period profits $E(y_1)$. Therefore, we ignore first-period profits in the subsequent analysis. Let $f(y_1 \mid h)$ denote the density of y_1 for a given hedging choice h. Then, the incumbent's second-period profit Π – from an *ex-ante* perspective – is given by

$$\begin{aligned} \Pi &= \int_{-\infty}^{y^*} E(\eta \mid y_1, h) f(y_1 \mid h) dy_1 + (1-\delta_I) \int_{y^*}^{+\infty} E(\eta \mid y_1, h) f(y_1 \mid h) dy_1 \\ &= \bar{\eta} - \underbrace{\delta_I \int_{y^*}^{+\infty} E(\eta \mid y_1, h) f(y_1 \mid h) dy_1}_{=:\text{ Expected profit reduction from entry } V(y^*, h)} . \end{aligned} \tag{10}$$

If $y_1 > y^*$ entry occurs and the incumbent receives $(1-\delta_I)E(\eta \mid y_1, h)$; otherwise, the entrant chooses to not enter and the incumbent remains monopolist with profit $E(\eta \mid y_1, h)$, where $E(\eta \mid y_1, h)$ reflects the expectation of the *unknown* market quality η conditional on *observed* first-period profits y_1 and *actual* hedging strategy h. Since $E(\eta \mid y_1, h)$ is a linear function of the random variable y_1, it is itself normally distributed. In (10), the first expression represents the *expected monopoly profit,* and the second expression represents the *expected profit reduction from market entry* $V(y^*, h)$. To maximize profits, the incumbent chooses h so as to minimize $V(y^*, h)$. The result of this optimization characterizes the set of strategies that is individually optimal for the incumbent, given a conjectured entry threshold of y^*.

Lemma 2 *Given any conjecture about the entry threshold y^*, the incumbent's expected (second-period) profit Π has no local maximum on $h \in [0,1]$. Its maximum h^* is attained on the boundaries of $h \in [0,1]$. A unique cutoff $\hat{y} \in (A, B)$ exists such that*

$$\begin{aligned} h^* &= 1 \quad &&\text{for} \quad y^* > \hat{y}, \\ h^* &= 0 \quad &&\text{for} \quad y^* < \hat{y}, \text{ and} \\ h^* &\in \{0,1\} \quad &&\text{for} \quad y^* = \hat{y}, \end{aligned}$$

where

$$A := \frac{1}{2}\left(\bar{\eta} + \sqrt{\bar{\eta}^2 + 4\sigma_\eta^2}\right) \text{ and } B := \frac{\bar{\eta}(\sigma_\eta^2 - \sigma_\epsilon^2)}{2\sigma_\eta^2} + \frac{1}{2}\sqrt{\frac{(\sigma_\eta^2 + \sigma_\epsilon^2)(4\sigma_\eta^2 + \bar{\eta}^2(\sigma_\eta^2 + \sigma_\epsilon^2))}{\sigma_\eta^4}}.$$

Proof. See appendix. ■

Lemma 2 establishes that the best reply of the incumbent to any threshold strategy is always unique and pure except for $y^* = \hat{y}$. For $y^* \neq \hat{y}$, the incumbent either chooses to fully hedge ($h^* = 1$) or to leave its exposure completely open ($h^* = 0$). For example, if the incumbent believes the entrant has an entry threshold higher than $\hat{y}$, the best response is $h^* = 1$. For $y^* = \hat{y}$, the incumbent is indifferent between *full hedging* with $h^* = 1$ and *no hedging* with $h^* = 0$; all intermediate hedging levels, $h^* \in (0,1)$, imply strictly lower profits to the incumbent. The incumbent's best response includes any mixture of $h^* = 1$ and $h^* = 0$.[11]

To capture the intuition for this result, it is helpful to explore the effects of a marginal change in h on the incumbent's profits Π. To do so, we rewrite $V(y^*, h)$ using previous results.

$$\begin{aligned} V(y^*, h) &= \delta_I(\alpha\left[\bar{\eta} * (1 - F(y^* \mid h)) + \sigma_y^2 f(y^* \mid h)\right] + (1-\alpha)\bar{\eta}(1 - F(y^* \mid h))) && (11) \\ &= \delta_I\left[\bar{\eta}(1 - F(y^* \mid h)) + \sigma_\eta^2 f(y^* \mid h)\right] \\ &= (1 - F(y^* \mid h)) \cdot \underbrace{\delta_I\left(\bar{\eta} + \sigma_\eta^2 \frac{f(y^* \mid h)}{1 - F(y^* \mid h)}\right)}_{=\delta_I E(\eta \mid y_1, h, y_1 \geq y^*)}, && (12) \end{aligned}$$

where $F(\cdot)$ is the cumulative distribution of y_1, and $1 - F(y^* \mid h)$ denotes the probability that entry occurs since first-period profits realize above the entry threshold y^*. Note that the first line follows from using (5) as well as well-known results concerning censored normal distributions. The second line follows from substituting α from condition (7). We find the third line particularly useful for the subsequent analysis. It captures the basic relationship between means of truncated and censored normal distributions.[12]

[11] Note that no closed-form solution for $\hat{y}$ exists. We show uniqueness and existence of $\hat{y}$ in the appendix.

[12] Put more technically, $V(y^*, h)$ is obtained as follows. Suppose a random variable $x \sim N(\mu, \sigma^2)$ censored on $x \leq a$. Then, the *censored* mean yields $\int_a^\infty x f(x) dx = (1 - \Phi(\beta))\mu + \sigma\phi(\beta) = (1 - F(a))\mu + \sigma^2 f(a)$, where $\beta = (a - \mu)/\sigma$, ϕ/Φ is the

Equation (12) has an intuitive interpretation. The expected profit reduction from market entry, $V(y^*, h)$, equals the *probability of market entry,* $1 - F(y^* \mid h)$, multiplied by the *expected profit reduction to the incumbent conditional on entry.* Consequently, the total change in Π with respect to h is due to two effects:

$$-\frac{\partial V(y^*, h)}{\partial h} = \underbrace{\frac{\partial\left(1 - F(y^* \mid h)\right)}{\partial h}\left(-\delta_I\left(\bar{\eta} + \sigma_\eta^2 \frac{f(y^* \mid h)}{1 - F(y^* \mid h)}\right)\right)}_{\text{(a) "Probability Effect" (+)}} + \underbrace{\left(1 - F(y^* \mid h)\right)\left(-\frac{\partial}{\partial h}\delta_I\left(\bar{\eta} + \sigma_\eta^2 \frac{f(y^* \mid h)}{1 - F(y^* \mid h)}\right)\right)}_{\text{(b) "Information Effect" (-)}}. \tag{13}$$

It is simply the sum of (a) the marginal change in the probability of market entry weighted by the *conditional* profit reduction if y_1 *is* exceeding y^* ("Probability Effect") and (b) the marginal change in this conditional profit reduction weighted by the probability of market entry ("Information Effect").[13] The intuition is as follows.

(a) Probability Effect. A higher level of hedging lowers the dispersion of the incumbent's realized first-period profit y_1. As a consequence, hedging shifts probability mass below the entry threshold y^*, which due to assumption (4) is larger than the ex ante expected market profitability $\bar{\eta}$, and makes outliers to the right tail of the distribution less likely. It simply affects the probability that the observation falls in the part of the distribution that induces the rival to enter the market. More hedging hence mitigates the probability of entry and lowers the expected loss to the incumbent. Thus, the Probability Effect provides an incentive for the incumbent to fully hedge its transitory exposure. Figure 2 gives an intuitive graphical representation of this effect.

density / the cumulative distribution of the standard normal distribution and f /F is the density / the cumulative distribution of x. Further, suppose a normally distributed random variable x truncated on $x \leq a$. Then, the *truncated* mean yields $E(x \mid x \geq a) = \int_a^\infty x f(x \mid x \geq a)dx = \frac{E(x^*)}{Prob(x \geq a)} = \frac{E(x^*)}{1-F(a)}$, where $f(x \mid x \geq a) = \frac{f(x)}{1-F(a)}$, and $E(x^*)$ denotes the censored mean derived above (see, e.g., Greene, 2003, p. 758-763, or Johnson, Kotz, and Balakrishnan, 1995, p.156, for further reference).

[13] A formal investigation of the Probability and Information Effects is in the appendix.

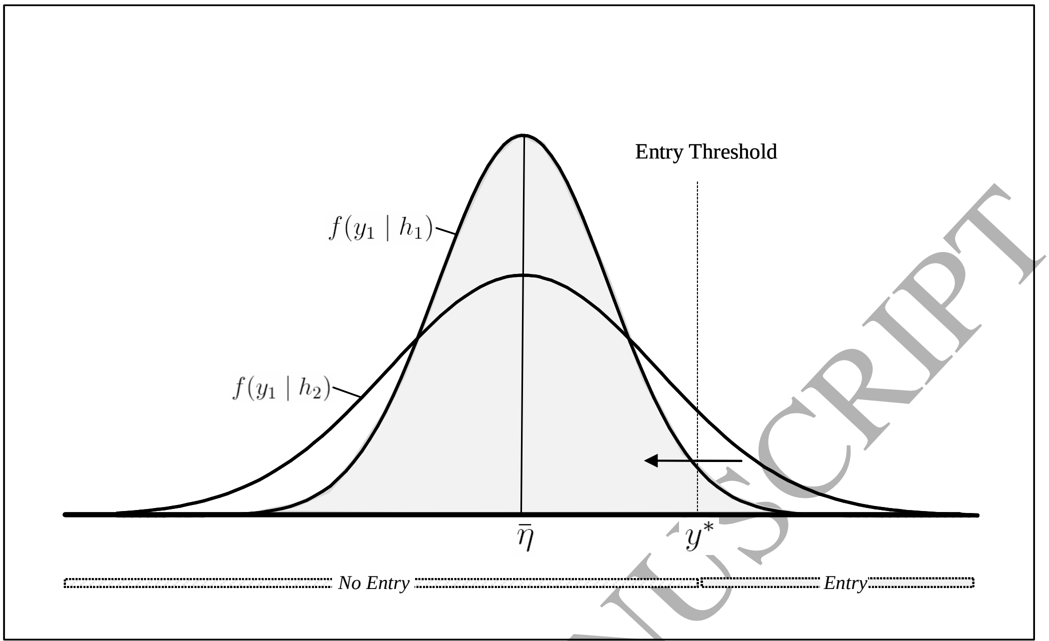

Figure 2: "Probability Effect" for strategies h_1 and h_2, where $h_1 > h_2$.

(b) Information Effect. The incumbent's conditional profit reduction depends on the distribution of states of market quality η for which, based on a given entry threshold y^*, entry occurs. For example, if the incumbent fully hedges its entire transitory exposure, entry takes place only if the realized η is indeed above y^*. However, if the incumbent does not hedge, the entrant may refrain from entering with a certain probability even if η is large or enter even though entry is not profitable. Such "errors" by the entrant turn out to be profitable for the incumbent as entry decreases the incumbent's profits proportionally to market quality. Less hedging hence mitigates the profit loss if entry should occur. So while the Probability Effect suggests the incumbent has clear incentives to hedge, the Information Effect works into the opposite direction.

An important observation is that the incumbent's expected gain (Probability Effect) from hedging increases with y^*. The intuition is that the incumbent's profit reduction conditional upon entry (the second factor in the first line of (13)) increases with y^*. At the same time, the incumbent's expected loss from hedging (Information Effect) decreases with y^*. Then, the likelihood of reaching states in which profitable entry errors may occur, $(1 - F(y^* \mid h))$ (the second factor in the second line of (13)), becomes relatively low. For y^* sufficiently large, the Probability Effect outweighs the Information Effect. Instead, if the entry threshold y^* is relatively small, the Information Effect dominates.

We now construct the equilibrium of our model, which Proposition 1 summarizes.

Proposition 1 *In a non-disclosure regime with unobservable risk management activity, a unique equilibrium exists. Depending on parameter values, the equilibrium strategy of the incumbent is either:*

(a) full hedging ($h^* = 1$) with an entry threshold of $y^* = \frac{K}{1-\delta_R}$, whenever $\frac{K}{1-\delta_R} > \hat{y}$;

(b) no hedging ($h^* = 0$) with an entry threshold of $y^* = \frac{K}{1-\delta_R} + \frac{\sigma_\epsilon^2}{\sigma_\eta^2}\left(\frac{K}{1-\delta_R} - \bar{\eta}\right)$, whenever $\frac{K}{1-\delta_R} + \frac{\sigma_\epsilon^2}{\sigma_\eta^2}\left(\frac{K}{1-\delta_R} - \bar{\eta}\right) < \hat{y}$; or

(c) a mixed strategy between $h^* = 1$ (with probability p^*) and $h^* = 0$ (with probability $1 - p^*$) with an entry threshold of $y^* = \hat{y}$, otherwise.

Proof. See appendix. ■

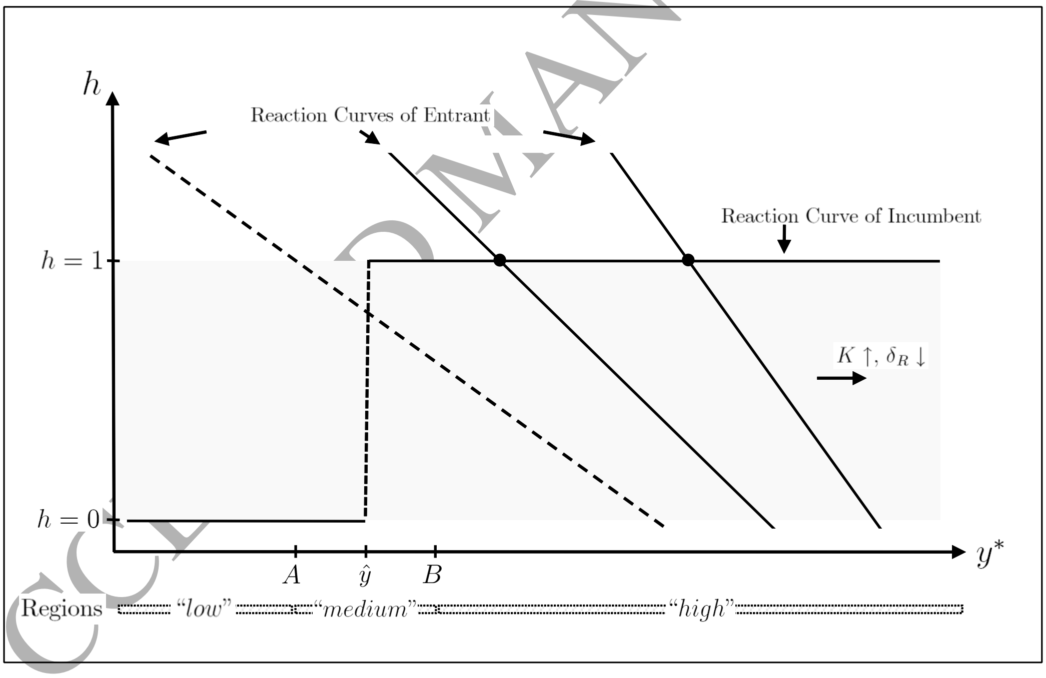

Figure 3: A graphical representation of the (pure-strategy) reaction curves of incumbent and entrant.

Depending on parameter values, (unique) pure or mixed strategy equilibria arise. In Figure 3, we illustrate the construction of *pure-strategy equilibria.* Recall that (8) gives the entrant's best response curve to an arbitrary (pure-strategy) conjecture h^*, and Lemma 2 gives the incumbent's best response to an arbitrary conjecture y^*. The unique intersection of these best response curves – as depicted in Figure 3 – pins down the pure-strategy equilibrium. Then, the best response of either firm is consistent with the other firm's belief. For ease of notation, let in the following y^* and h^* denote the equilibrium strategies.[14]

Proposition 1 demonstrates that three cases exist. In the first and most interesting case, when parameters are such that the equilibrium entry threshold is above the cutoff $\hat{y}$, engaging in risk management activities is optimal for the incumbent. The threat of entry creates strong forces to reduce risk – even though the incumbent is risk-neutral. In the second case, when the equilibrium entry threshold y^* is below the cutoff $\hat{y}$, the incumbent does not have an incentive to hedge. Although risk management still would increase the chances that the entrant stayed out of the market, the incumbent would suffer disproportionately from an increased profit reduction if entry should occur. The incumbent garbles the signal to the entrant. In the third case, a mixed strategy equilibrium occurs. The incumbent is indifferent between playing $h^* = 1$ and $h^* = 0$ and hence randomizes between both strategies. When the incumbent randomizes over these strategies, the induced outcome to the entrant corresponds to a lottery over the pure-strategy payoffs weighted by the probabilities that the incumbent assigns to $h^* = 0$ and $h^* = 1$. The randomization schedule is chosen such that the entrant optimal threshold is $y^* = \hat{y}$. Hence, $p^* \in (0, 1)$ solves

$$(1 - \delta_R)\left(p^* E(\eta \mid \hat{y}, h^* = 1) + (1 - p^*) E(\eta \mid \hat{y}, h^* = 0)\right) = K. \tag{14}$$

4.1.3 Numerical Example

We illustrate Proposition 1 with a numerical example for three settings. Table 1 presents equilibria for various entry costs K with all other parameters held fixed. Each column shows, for a particular entry cost K, the equilibrium strategies (h^*, y^*), the *expected* second-period profits of incumbent and entrant (Π_I^*, Π_R^*), and the entry probability (q^*). The examples involve a market quality η that is drawn from a normal distribution with mean $\bar{\eta} = 50$ and standard deviation $\sigma_\eta = 20$. The incumbent's exposure ϵ is drawn from a normal distribution with mean zero and standard deviation $\sigma_\epsilon = 10$. The effects of competition are captured by $\delta_I = \delta_R = 0.6$, which implies (as in the standard Cournot situation) total profits in a duopoly are lower than

[14]The two rightmost (solid) reaction curves of the entrant represent two different parameter configurations that lead to the hedging equilibria ($h^* = 1$) of Proposition 1a. Note that the intersection of the (dashed) leftmost reaction curve of the entrant and the dashed vertical line at $\hat{y}$ cannot be translated into a mixed strategy equilibrium. However, a mixed strategy equilibrium exists for this parameter configuration, see next paragraph and condition (14).

in a monopoly. Given these parameter values, it can be easily verified that the interval [57.02, 57.18] contains the discrete jump of the incumbent's best reaction function $h(y^*)$ at $\hat{y}$ as shown in Figure 3.

Recall that $\hat{y}$ cannot be solved for analytically. Nevertheless, a numerical solution, which is $\hat{y} = 57.096$, can be obtained. Then, it is straightforward to show that if $K \leq 22.27$, the incumbent does not hedge ($h^* = 0$), whereas if $K \geq 22.84$, the incumbent engages in risk management ($h^* = 1$).[15] Otherwise, the incumbent chooses a mixed strategy $p^* \in (0,1)$. Therefore, each of the three entry cost levels in Table 1, namely $K = 21.9$, $K = 22.6$, and $K = 23.2$, corresponds to one of the three different regions displayed in Figure 3. Notice also that the expected second-period profits of the incumbent Π_I^* strictly increase in K, whereas the expected second-period profits of the entrant Π_R^* and the entry probability q^* strictly decrease in K.

Parameters	$\bar{\eta} = 50$, $\sigma_\eta = 20$, $\sigma_\epsilon = 10$, $\delta_I = 0.6$, $\delta_R = 0.6$		
	Region "low"	Region "medium"	Region "high"
Entry cost	$K = 21.9$	$K = 22.6$	$K = 23.2$
Equilibrium results	$h^* = 0$	$p^* = 0.5$	$h^* = 1$
	$y^* = 56$	$y^* = \hat{y} = 57.096$	$y^* = 58$
	$\Pi_I^* = 34.0$	$\Pi_I^* = 34.6$	$\Pi_I^* = 35.2$
	$\Pi_R^* = 2.0$	$\Pi_R^* = 1.91$	$\Pi_R^* = 1.84$
	$q^* = 0.39$	$q^* = 0.37$	$q^* = 0.35$

Table 1: A numerical example illustrating the effect of an increasing entry cost K.

4.2 Risk Management and Market Entry when Hedging Choice is Observable

We now consider the case in which the entrant observes h. This case corresponds to a regime with additional mandated disclosures of a firm's risk management activities. We explore the economic consequences of such requirements on the equilibrium hedging behavior and market entry. As we will see below, the incumbent's hedge decision serves as a commitment device which strategically affects the entrant's entry threshold, thereby providing incentives to the incumbent to reduce hedging activities.

Because risk management activities are revealed, the model turns into a game with sequential play. Solving for the (subgame perfect) equilibrium is straightforward. The incumbent must anticipate the optimal reaction

[15] These bounds for K can be easily derived by solving for K in the two cases in which the reaction curve of the entrant crosses either $(\hat{y}, 0)$ or $(\hat{y}, 1)$.

of the entrant to both, the *hedging strategy* h of the incumbent and the observed *first-period profit* y_1. Entry takes place if (and only if) expected post-entry profits exceed the cost of entry

$$(1-\delta_R)E(\eta \mid y_1, h) > K,$$

which by using (5) implies entry, if y_1 exceeds the threshold value

$$y^*(h) := \beta + \gamma(1-h), \tag{15}$$

where

$$\beta := \frac{K}{1-\delta_R} \text{ and } \gamma := \frac{\sigma_\epsilon^2}{\sigma_\eta^2}\left(\frac{K}{1-\delta_R} - \bar{\eta}\right).$$

A similar condition for market entry appeared in the analysis of the non-disclosure regime in section 4.1 (recall the entrant's optimal entry decision from equation (8)). However, in the regime we consider here, the threshold value $y^*(h)$ is truly the entrant's reaction to the *observed* hedging strategy h (and hence a function of h), whereas in the earlier analysis, y^* is the entrant's response to an *unobserved, conjectured, and fixed* hedging choice. Thus, $y^*(h)$ gives an entry schedule specifying the entrant's optimal choice for each *observed* action of the incumbent, h, and each first-period profit realization, y_1. Since the incumbent can solve for the entrant's optimal choice as easily as the entrant can, the incumbent anticipates that its hedge decision h will be met with the reaction $y^*(h)$.

As a consequence, the incumbent's profit maximization as characterized in (10) to (12) now yields

$$\max_{h\in[0,1]} \bar{\eta} - \underbrace{\delta_I \int_{y^*(h)}^{+\infty} E(\eta \mid y_1, h) f(y^*(h), h) dy_1}_{=:\text{Profit reduction from market entry } V(y^*(h),h)}. \tag{16}$$

This maximization problem is similar to the one analyzed in section 4.1.2. The difference is that the incumbent can now elect a point on the entrant's reaction function $y^*(h)$ that maximizes its own expected profits. The entrant's reaction function $y^*(h)$ enters the incumbent's maximization through the lower limit of the integral.

Before proceeding with the analysis of the equilibrium, we state our central result.

Proposition 2 *In a mandatory hedge disclosure regime with observable risk management activity, a unique (subgame perfect) equilibrium exists. In this equilibrium, the incumbent does not hedge ($h^* = 0$). The threshold value $y^*(h^*)$ above which the entrant chooses to enter the market in equilibrium is given by $y^*(h^* = 0) = \frac{K}{1-\delta_R} + \frac{\sigma_\epsilon^2}{\sigma_\eta^2}\left(\frac{K}{1-\delta_R} - \bar{\eta}\right)$.*

Proof. See appendix. ■

The proposition states that a mandatory hedge disclosure regime may drive firms to decrease risk management activities. Risk management is now a device to directly influence the entry threshold, $y^*(h)$, above which the entrant chooses to enter the market. Disclosure creates a first-mover advantage; the incumbent is able to influence the rivals' beliefs. To see the intuition, differentiate the entry threshold in (15) with respect to h. Using (4) implies $\gamma > 0$; hence, more hedging strictly decreases $y^*(h)$. Such downward shift clearly invites entry because profits must realize less sharply above the prior to trigger entry. In contrast, if the incumbent hedges less, realized profits y_1 are a less precise signal of η, which results in an upward shift of $y^*(h)$. Such upward shift in the entry threshold is clearly beneficial to the incumbent and is in fact the dominating effect in Proposition 2.[16] Put more technically, the influence of hedging on the entry threshold changes the marginal effects of hedging on the incumbent's profits (see equation 13) – particularly the probability of entry. As we show in the appendix, the Probability Effect and the Information Effect now have the same (negative) sign. Hedging becomes detrimental to the incumbent for the entire permissible parameter space: h *increases* the probability of market entry and *increases* the expected loss if market entry occurs. Note that the result in Proposition 2 does not depend on the values of δ_I or δ_R. This implies that the result holds even if post-entry profits in the disclosure regime are different from those in case of non-disclosure.

Consequently, the implication of Proposition 2 is that the incumbent has an incentive to obfuscate the information conveyed through the first-period profit y_1 and that mandatory disclosure encourages risk-taking. The natural incentives to engage in hedging activity under many circumstances as Proposition 1 posits are destroyed.

4.3 Empirical Implications and Discussion

Propositions 1 and 2 shed light on equilibrium strategies of the incumbent and the entrant. We now examine the broader economic consequences of alternative hedge disclosures. We also present a number of testable implications of the model and discuss results from the related literature.

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[16]By comparing the lower limits of the integration in (10) and (16), it is easy to see that this strategic effect of hedging does not exist in the earlier analysis of unobservable hedging. The difference in the technical treatment is that the strategic interaction between the incumbent and the entrant under observability is captured by the total derivative of (16) with respect to h, $\frac{d\Pi(y^*(h),h)}{dh}$.

4.3.1 Implications on Corporate Risk Management

Firms have strong incentives to engage in corporate risk management in the presence of market imperfections that induce concavities in the firm's payoff functions (e.g., convex tax schedules, deadweight costs of financial distress, or costs of external financing; see Smith and Stulz, 1985; Stulz, 1990; Froot, Scharfstein, and Stein, 1993). Our model identifies the threat of entry as a previously unrecognized determinant of corporate risk management when accounting standards imply that such decisions remain undisclosed.

Corollary 1 *Risk management activity in a mandatory hedge disclosure regime is (weakly) lower than risk management activity in a non-disclosure regime.*

Our theory suggests that when moving from a non-disclosure to a mandatory hedge disclosure regime, firms tend to reduce corporate risk management. Sapra (2002) and DeMarzo and Duffie (1995) reach a similar conclusion. Sapra (2002) advances an argument for why derivatives disclosure regulation affects futures positions. Like our model, Sapra's (2002) approach predicts the reduction of risk management in response to increased hedge disclosures. The reason for it is very different, however. In his model, private information allows firms to take profitable positions in the futures market. When derivatives positions are observable, firms have the possibility to signal private information. An aggressive futures position sends a *positive signal* to the financial market and thereby maximizes the financial market price. In our model, the incumbent *reduces* the probability of sending a *sufficiently positive signal* to the entrant by refraining from hedging.[17]

DeMarzo and Duffie (1995) attribute an inclination to hedge less when hedge positions are observable to incentive conflicts between managers and its shareholders, rather than to the interaction of competing firms. In DeMarzo and Duffie (1995), corporate profits serve as a signal of managerial ability, which shareholders and managers use to (re-)negotiate wage contracts. In their non-disclosure regime, risk averse managers have strict incentives to hedge, because reduced profit variability implies reduced income risk. In our model, even risk-neutral firms have incentives to hedge if discouraging entrants to compete (by hedging more) is more important than eroding the informational basis of the entry decision (by hedging less). Disclosure typically destroys these equilibria in both models as it tends to reverse incentives: In DeMarzo and Duffie (1995), disclosure allows the manager to *reduce income risk* by hedging *less*, because doing so results in a lower sensitivity of a manager's future wage to corporate profits. Their result holds if the net effect of hedging less

[17] Also, Sapra and Shin (2008) show that tighter standards of derivatives disclosure coupled with marking-to-market of the derivatives can reduce firms' risk management incentives.

(decreased sensitivity of wage to profits vs. increased risk in profits) is positive. In our model, the effect of hedging results from changes in *the level of expected firm profits* (from discouraging potential entrants to enter) instead of from changes in *firm profit variability.* Lastly, in DeMarzo and Duffie (1995) the information-revealing party is always better off the higher the first-period profit, because large profits are indicative of a skilled manager. This relationship does not (always) hold for the revealing party in our model, because larger first-period profits may punish the incumbent by triggering entry.

4.3.2 Implications on Entry Probability, Competition, and Social Welfare

Corollary 2 *The probability of entry in a mandatory hedge disclosure regime is (weakly) lower than the probability of entry in a non-disclosure regime.*

Proof. See appendix. ■

Because hedge disclosures increase uncertainty about market quality (by discouraging risk management), entry barriers rise. Therefore, entry rates in the industry that the firm belongs to should tend to fall, which subsequently raises industry concentration. Consequently, our theory implies both a decrease in entry rates and an increase in industry concentration (measured, e.g., by a change in the Herfindahl index) in response to accounting changes that increase hedge disclosure. Typical ways to measure entry are, e.g., the number of new entrants as a percentage of the total number of firms in the industry or the share of industry employment/sales by new entrants – both net or gross of exit (see Geroski, 1991, Aghion et al., 2004; Aghion et al., 2009). Reduced entry is most likely undesirable from a social and economic point of view for most industries. The lower probability of entry reduces social surplus in any typical concretization of our reduced-form market representation, for instance, in a standard model of quantity competition or of price competition with capacity constraints. Social surplus (measured as the sum of producer and consumer rents) is typically higher in duopoly than in monopoly.

A particularity of pre-entry competition in the context of our theory is worth noting. Hedge disclosure regulation applies asymmetrically to the two competitors. Whereas one competitor (the entrant) remains passive in period one, mandatory hedge disclosure serves as an instrument for the other one (the incumbent) to make its own level of hedging observable. The incumbent's strategically superior position generated by tighter hedge disclosure requirements allows it to reap additional profits at the expense of the entrant. However, such profit transfer from the entrant to the incumbent is generally not sufficient for a diminished social surplus. For such welfare loss, it matters how the firms' equilibrium actions affect firms' profits *and* consumer surplus.

In principle, the entrant's welfare-decreasing higher entry threshold in period 2 could be compensated for by a welfare enhancing-action by the incumbent in period 1. This is not the case here. The incumbent responds to hedge disclosure requirements by hedging less which is welfare-neutral in period 1 (because hedging does not affect $E(y_1)$). An environment in which the committing party's action is welfare-enhancing is presented in Hughes and Williams (2008). In a setting of post-entry quantity competition (and one-sided pre-production commitment) the committing party commits to a relatively high level of production. This generates a higher welfare level than when commitment is impossible.

4.3.3 Implications on Informativeness of Corporate Earnings and Earnings Volatility

Corollary 3 *The variance of the incumbent's first-period profit is (weakly) higher in a mandatory hedge disclosure regime than in a non-disclosure regime. Also, the informativeness of profits about a firm's intrinsic value in a mandatory hedge disclosure regime is (weakly) lower than the informativeness of profits in a non-disclosure regime.*

Proof. The variance of first-period profits is given by $\sigma_\eta^2 + \sigma_\epsilon^2$ (mandatory hedge disclosure regime) and σ_η^2 (non-disclosure regime). Comparing the "signal-to-noise ratios" yields $\frac{\sigma_\eta^2}{\sigma_\eta^2+\sigma_\epsilon^2} < \frac{\sigma_\eta^2}{\sigma_\eta^2} = 1$. This establishes the corollary. ∎

Two empirical implications emerge from the corollary. First, profits in a mandatory disclosure regime are more volatile as firms' risk management activities are reduced. As a result, we expect to observe a higher variability in firms' profits following a change of accounting standards towards stricter hedge disclosure.

Second, profits are less informative and become less useful indicators for a firm's value. Less risk management implies a lower signal-to-noise ratio due to more total variance in profits from noise. Hence, our model suggests that a regulator's attempt for greater transparency may actually lead to more severe informational asymmetries. Such decrease in earnings informativeness is typically detrimental to capital markets, for example, because it leads to slower learning about management quality (DeMarzo and Duffie, 1995) and more frequent misvaluations of firms' financial claims resulting in distorted allocation of capital.

4.3.4 Implications for the Cross-Section of Firms

Corollaries 1-3 have both on-average implications for the economy and implications for the cross-section of firms, that is the specific circumstances under which hedge disclosures are more likely to affect economic behavior. Satisfying the parameter values of Proposition 1a as well as the model's parametric assumptions (condition 4) requires

- a considerable cost of entry (K high), for example, in capital-intensive or advertising- intensive industries in which capital requirements in order to compete or enter a market are high; and/or
- moderate post-entry rents of the entrant (δ_R high). A low level of rents of the entrant can arise, for example, due to both the entrant's weak market position after entry (δ_I low and δ_R high) or intense post-entry competition (both δ_I and δ_R high).

It is in such markets that the consequences of stricter hedge disclosure regulation are most (or at least more) likely. Because disclosure rules affect primarily public firms, the competitive effect of hedge disclosure is also more pronounced in industries with a high fraction of public firms.

4.4 Extensions

4.4.1 Profit Functions and Fixed Amount Duopoly Loss

One of the characteristics of our model of hedge disclosure is that hedging affects the level of uncertainty under which the entrant makes its decision. If the incumbent does not fully hedge, the entrant may either enter even though doing so involves a loss (type-I error) or may refrain from entering even though entering would be profitable (type-II error). Given the proportional reduction of incumbent profits upon entry as defined in (2), such mistakes affect the incumbent's expected profit: the incumbent's loss of entry despite a low market quality is smaller than the incumbent's benefit of non-entry in case of a high market quality. This mechanism (the Information Effect) provides the incumbent with an incentive to refrain from hedging and is responsible for the outcomes described in Proposition 1b and 1c.

It is worth noting that if the Information Effect is immaterial, the incumbent hedges for the entire space of permissible parameters if hedging is not observable. For example, in a more restrictive setting if entry imposed a fixed loss of profit for the incumbent, the Information Effect would be zero in equilibrium.[18] To see the logic, assume that the incumbent's duopoly profit from post-entry competition as given in (2) is

[18] See Wagenhofer (1990) for an oligopoly model in which increased (post-entry) competition imposes fixed proprietary cost on an incumbent firm.

$y_{I,2} = \eta - C$, where $C > 0$ is the *fixed* loss in the incumbent's profits due to increased competition if entry occurs. Then, (10) simplifies to

$$\Pi = \bar{\eta} - \int_{y^*}^{+\infty} C \ f(y_1 \mid h) dy_1 = \bar{\eta} - C(1 - F(y^* \mid h)).$$

To maximize profits, the incumbent minimizes the entry probability, $1 - F(y^* \mid h)$ and hedges for the entire permissible parameter space. This result implies stronger differences in hedging activities between the observability regimes.

As a consequence, changes in hedge disclosures are more likely to affect economic behavior in situations in which the effect of entry on incumbent profits is relatively similar across states or entry affects the incumbent's loss irrespective of market quality.

4.4.2 Cost of Disclosure and Voluntary Disclosure

Risk management activities are informationally complex. Therefore, the literature on disclosure and hedging typically abstracts from the possibility to disclose a firm's risk management activities voluntarily (see section 2).[19] The nature of risk management activities suggests that credible disclosure of risk management activities or their verification are sufficiently costly if done in isolation by individual firms: Credible disclosure of risk management activities requires substantial investments of the disclosing firm in disclosure technology.[20] In addition, infrastructure investments in verification technology by central authorities, the auditing industry and consumers of financial reporting information must complement such investments by individual firms to limit information processing costs.[21] At the very least, an environment of voluntary disclosure of risk management activities requires a *mandated set of formal rules and associated penalties* that are coordinated, implemented and maintained by central authorities. Hence, voluntary disclosure of risk management activities without reporting regulation and standardization is very unlikely.

[19] See Beyer et. al. (2010), Verrecchia (2001) and Dye (2001) for the conditions under which firms disclose voluntarily and the extant literature on market imperfections that make voluntary disclosure unlikely.

[20] In fact, current hedge disclosure requirements already impose substantial direct and managerial opportunity costs on firms, mainly due to the complexity to objectively measure and certify risk management (see Lins, Servaes, and Tamayo, 2011). Complex accounting regulations related to hedging and risk also impose significant restatement and litigation risks on firms (see, for example, Corman, 2006).

[21] Such "information processing costs" have only recently been incorporated in the finance literature (see, for example, Ayotte and Bolton, 2011).

For that reason, current hedge disclosure regulations concentrate on a limited set of (financial) instruments and (market) risks that are reliably measurable and identifiable – rather than on the comprehensive set of risks and risk management activities. This focus limits infrastructure investments, but allows firms to engage in one-sided disclosure: when a firm discloses a hedging policy, say via futures, it has the opportunity to further reduce its exposure to certain risks without disclosure, say via off-balance measures such as insurance contracts.[22] In terms of the model, we can represent these considerations by separating the level of hedging into a disclosed part $h^d \geq 0$ and an undisclosed part $h^{nd} = h - h^d \geq 0$ to be chosen simultaneously. This formulation implies that a firm is able to hedge more than it reports, because it can engage in risk management activities not reflected in current accounting standards. Thus, the firm chooses the extent to which it discloses its risk management activities by selecting the instruments used to hedge even if accounting regulations mandate hedge disclosure.[23] We can interpret this type of partial disclosure as a typical form of *voluntary* and *one-sided* disclosure of individual risk management activities; firms can choose their mix of risk management activities, which implies that they disclose their level of h^d voluntarily.

The noteworthy result is that voluntary, one-sided disclosure of risk management activities yields equilibrium hedging levels equivalent to the ones in the non-disclosure regime. The intuition is as follows. First, note that a voluntarily disclosed level of $h^d = 0$ is equivalent to the non-disclosure regime (and thus yields the outcomes specified in Proposition 1), because the firm's hedging decision $h = h^{nd}$ remains unobserved. Second, note that raising the choice of h^d to a positive level makes the incumbent worse off for the parameters of Proposition 1b. Committing to any $h^d > 0$ leads to strictly lower expected profits than if $h^d = 0$ is chosen. The reason is that for any entry threshold, the incumbent maximizes its expected profit at either $h = 0$ or $h = 1$, or both (see Lemma 2). Any hedging level between the two polar values yields a strictly lower profit to the incumbent. For parameters of Proposition 1b, $h^d > 0$ eliminates the profit-maximizing hedging level of $h = 0$. Third, for the parameters of Proposition 1c, choosing $h^d > 0$ eliminates the mixed strategy equilibrium described in the proposition and hence any equilibrium. Thus, the firm picks $h^d = 0$ and a mixed strategy between $h^* = 0$ and $h^* = 1$. Fourth, for the parameters of Proposition 1a, choosing $h^d > 0$ does not affect the equilibrium outcome $h^* = 1$ of the non-disclosure case. The relevant parts of the reaction curves of the incumbent and the entrant (see Figure 3) are unaffected by any $h^d > 0$, which leaves the equilibrium hedging level $h^* = 1$. The firm picks an arbitrary level of h^d and $h^* = 1$.

[22] See Bodnar et al. (2011) and Servaes et al. (2009) for the prevalence of off-balance measures to manage risk.

[23] In practice, switching costs are likely to exist because hedging instruments are frequently tailored to hedge specific types of exposure.

In sum, voluntary, one-sided disclosure of risk management activities does not eliminate the equilibrium hedging levels of the non-disclosure regime. The reason is that choosing h^d lacks the commitment character of selecting a low h that is necessary for the outcome of the disclosure regime described in Proposition 2. However, when standard setters move towards more transparent disclosure regulation by incorporating more hedging activities into reporting, firms' opportunities to move flexibly between the categories of risk management activities to manage disclosure diminish. If all potential hedging activities have to be disclosed, the equilibrium outcome, $h^* = 0$, as described in Proposition 2 prevails.

5 Conclusion

Standard setters move increasingly toward further disclosure to add transparency on a firm's risk management practices. For instance, most recently (July 2014), the IASB published the final version of IFRS 9 *Financial Instruments.* This standard replaces IAS 39 *Financial Instruments: Recognition and Measurement* (1998) and may further increase the information provided to users of financial statements (IASB, 2014). However, such mandated requirements may also create unintended externalities.

In this paper, we examine one such externality and analyze the interaction between additional mandated hedge disclosures, corporate risk management, and pre-entry product-market competition. We show that mandating disclosure of a firm's risk position not only reduces entry rates, but impacts hedging decisions that may have other private and social welfare effects. If risk management is unobservable, even risk-neutral firms typically have strong incentives to engage in risk management activities in order to reduce the likelihood of entry. The model also demonstrates that under additional disclosure requirements, hedging may not be an equilibrium strategy if firms face the threat of entry in their product markets. Then, the incumbent's hedge decision serves as a commitment device to influence the entrant's beliefs and deter entry. While this paper is designed to specifically illustrate that hedge disclosures may distort corporate risk management, it also contributes to a growing literature that investigates the interaction between disclosure regulation and corporate financial policy.

A Appendix

A.1 Numerical Example 2

Table 2 continues the example from Table 1 and presents numerical solutions for both regimes.

Parameters	$\bar{\eta} = 50$, $\sigma_\eta = 20$, $\sigma_\epsilon = 10$, $\delta_I = 0.6$, $\delta_R = 0.6$		
	Region "low"	Region "medium"	Region "high"
Entry cost	$K = 21.9$	$K = 22.6$	$K = 23.2$
Equilibrium results	$h^*= 0$	$p^*= 0.5$	$h^*= 1$
(Regime 1)	$y^*= 56$	$y^*= \hat{y} = 57.096$	$y^*= 58$
	$\Pi_I^*= 34.0$	$\Pi_I^*= 34.6$	$\Pi_I^*= 35.2$
	$\Pi_R^*= 2.0$	$\Pi_R^*= 1.915$	$\Pi_R^*= 1.844$
	$q^*= 0.39$	$q^*= 0.37$	$q^*= 0.35$
Equilibrium results	$h^*= 0$	$h^*= 0$	$h^*= 0$
(Regime 2)	$y^*= 56$	$y^*= 57.98$	$y^*= 60$
	$\Pi_I^*= 34.0$	$\Pi_I^*= 35.2$	$\Pi_I^*= 36.3$
	$\Pi_R^*= 2.0$	$\Pi_R^*= 1.844$	$\Pi_R^*= 1.829$
	$q^*= 0.39$	$q^*= 0.36$	$q^*= 0.33$

Table 2: A numerical example illustrating the effect of an increasing entry cost K in both regimes.

A.2 Institutional Background

Documentation and testing requirements of accounting standards related to risk management place significant financial burdens on firms. Firms that engage in many hedging transactions suffer most. In the United States, two major standards govern disclosure of risk management activities.[24]

In June 1998, the Financial Accounting Standards Board (FASB) issued Statement of Financial Accounting Standards (SFAS) No. 133 (1998), entitled *Accounting for Derivative Instruments and Hedging Activities* – meanwhile significantly amended mainly by SFAS No. 138 (2000), SFAS No. 149 (2003), SFAS No. 155

[24]This section owes much to Ryan (2007) and several publications of the CFA Institute, most notably Gastineau, Smith, and Todd (2001).

(2006) – a detailed and complex set of accounting and disclosure requirements. Under these rules, accounting treatment generally requires derivatives to be "marked-to-market" on the balance sheet as assets or liabilities with changes in fair value recorded in net income. Under prior accounting standards, derivatives were either netted against the hedged item or not recognized in the balance sheet at all. The standard, however, permits special accounting treatment – "hedge accounting" – if firms meet a set of requirements regarding hedge effectiveness and documentation. Roughly speaking, if a transaction qualifies for this treatment, gains and losses of financial instrument and hedged item are recognized in net income in the same period: "Fair value hedge accounting" expands fair value accounting to the hedged item. "Cash flow hedge accounting" allows firms to recognize changes in the fair value of derivatives in "other comprehensive income (owner's equity)" on the balance sheet until the hedged transaction affects earnings. "Hedge accounting for net investments in a foreign operation" does not allow to account for gains or losses in net income; rather, firms must recognize changes directly in "other comprehensive income."

There is a *second* accounting standard that addresses financial instruments. The Financial Reporting Release (FRR) No. 48 (1997) of the Securities and Exchange Commission (SEC) requires public companies to report *forward-looking* numerical measures of their market risk exposures (i.e., to changes in interest rates, exchange rates, commodity prices, equity prices) related to financial instruments and derivatives. In January 1997, the SEC issued this new standard: *Disclosure of accounting policies for derivative financial instruments and derivative commodity instruments and disclosure of quantitative and qualitative information about market risk inherent in derivative financial instruments, other financial instruments and derivative commodity instruments.* FRR No. 48 sought to address the SEC's concern that risk of financial instruments was neither understood well enough by firms' top management nor presented in financial reports transparently and completely. Firms may choose from three alternative methods to disclose these risk categories: the tabular approach, the value-at-risk approach, and the sensitivity approach.

A.3 Proof of Lemma 2

The proof involves several steps. The procedure in the proof is (i) to show Π has no local maximum (the first part of the lemma) and (ii) to determine the behavior of $\frac{\partial \Pi(h)}{\partial h}$ on $h \in [0,1]$ for all admissible parameter values. The second step is the main difficulty. The proof involves three lemmas:

1. **Lemma 3:** *The incumbent's profit* Π *has no* ***local maximum*** *on* $h \in [0,1]$. *A unique* ***local minimum*** $h^0 \in (0,1)$ *exists if and only if* $A < y^* < B$, *where*

$$A := \frac{1}{2}(\bar{\eta} + \sqrt{\bar{\eta}^2 + 4\sigma_\eta^2})$$

and

$$B := \frac{\bar{\eta}(\sigma_\eta^2 - \sigma_\epsilon^2)}{2\sigma_\eta^2} + \frac{1}{2}\sqrt{\frac{(\sigma_\eta^2 + \sigma_\epsilon^2)(4\sigma_\eta^2 + \bar{\eta}^2(\sigma_\eta^2 + \sigma_\epsilon^2))}{\sigma_\eta^4}}.$$

2. **Lemma 4:** *On* $h \in [0,1]$, *if* $y^* \geq B$, *the incumbent's profit* Π *has a* ***global maximum***, *which is* $h^* = 1$, whereas *if* $y^* \leq A$, *the* ***global maximum*** *is* $h^* = 0$.

3. **Lemma 5:** *On* $h \in [0,1]$, *if* $A < y^* < B$, *a unique cutoff* $\hat{y}$ exists *such that if* $y^* > \hat{y}$ *then* $h^* = 1$, *whereas if* $y^* < \hat{y}$ *then* $h^* = 0$, and if $y^* = \hat{y}$ the incumbent is indifferent between $h^* = 1$ and $h^* = 0$.

Lemma 3 *The incumbent's profit* Π *has no* ***local maximum*** *on* $h \in [0,1]$. *A unique* ***local minimum*** $h^0 \in (0,1)$ *exists if and only if* $A < y^* < B$, *where*

$$A := \frac{1}{2}(\bar{\eta} + \sqrt{\bar{\eta}^2 + 4\sigma_\eta^2})$$

and

$$B := \frac{\bar{\eta}(\sigma_\eta^2 - \sigma_\epsilon^2)}{2\sigma_\eta^2} + \frac{1}{2}\sqrt{\frac{(\sigma_\eta^2 + \sigma_\epsilon^2)(4\sigma_\eta^2 + \bar{\eta}^2(\sigma_\eta^2 + \sigma_\epsilon^2))}{\sigma_\eta^4}}.$$

Proof. The procedure in the proof is straightforward. We solve for the usual first- and second-order conditions. Recall that σ_y^2 is a function of h

$$\sigma_y^2 := \sigma_\eta^2 + (1-h)\sigma_\epsilon^2; \tag{17}$$

thus, the density of y_1 at $y_1 = y^*$ given hedging choice h is

$$f(y^* \mid h) := \frac{1}{\sigma_y\sqrt{2\pi}} e^{-\frac{1}{2}(\frac{y^* - \bar{\eta}}{\sigma_y})^2}.$$

Recall from (12) that $V = \delta_I \left[(1 - F(y^* \mid h)) \times \bar{\eta} + \sigma_\eta^2 \times f(y^* \mid h)\right]$; hence

$$
\begin{aligned}
\frac{\partial \Pi(h)}{\partial h} &= -\delta_I \left[\bar{\eta}\frac{\partial(1 - F(y^* \mid h))}{\partial h} + \sigma_\eta^2 \frac{\partial f(y^* \mid h)}{\partial h}\right] \\
&= \delta_I \left[\bar{\eta}\frac{(y^* - \bar{\eta})\sigma_\epsilon^2}{2\sigma_y^2} f(y^* \mid h) + \sigma_\eta^2\ \sigma_\epsilon^2 \frac{(y^* - \bar{\eta})^2 - \sigma_y^2}{2\sigma_y^4}\ f(y^* \mid h)\right] \\
&= \delta_I f(y^* \mid h) \left[\bar{\eta}\frac{(y^* - \bar{\eta})\sigma_\epsilon^2}{2\sigma_y^2} + \sigma_\eta^2\ \sigma_\epsilon^2 \frac{(y^* - \bar{\eta})^2 - \sigma_y^2}{2\sigma_y^4}\right] \\
&= \delta_I f(y^* \mid h) \frac{\sigma_\epsilon^2}{2\sigma_y^4} \left[\bar{\eta}(y^* - \bar{\eta})\sigma_y^2 + \sigma_\eta^2\ \left((y^* - \bar{\eta})^2 - \sigma_y^2\right)\right], \qquad (18)
\end{aligned}
$$

where the second line follows from both using (23) and using

$$
\begin{aligned}
\frac{\partial f(y^* \mid h)}{\partial h} &= -f(y^* \mid h)\frac{(y^* - \bar{\eta})^2 \sigma_\epsilon^2}{2\sigma_y^4} + f(y^* \mid h)\frac{\sigma_\epsilon^2}{2\sigma_y^2} \\
&= -f(y^* \mid h)\sigma_\epsilon^2 \frac{(y^* - \bar{\eta})^2 - \sigma_y^2}{2\sigma_y^4}. \qquad (19)
\end{aligned}
$$

Substituting for (17) and solving the first-order condition $\frac{\partial \Pi(h)}{\partial h} = 0$ yields

$$
h^0 = \frac{\bar{\eta}(y^* - \bar{\eta})\sigma_\epsilon^2 + \sigma_\eta^2({y^*}^2 - y^*\bar{\eta} - \sigma_\epsilon^2) - \sigma_\eta^4}{\sigma_\epsilon^2(\bar{\eta}(y^* - \bar{\eta}) - \sigma_\eta^2)}. \qquad (20)
$$

Imposing $h^0 \in (0, 1)$ implies that h^0 is on the interval $(0, 1)$ if and only if

$$
\underbrace{\frac{1}{2}(\bar{\eta} + \sqrt{\bar{\eta}^2 + 4\sigma_\eta^2})}_{:=A} < y^* < \underbrace{\frac{\bar{\eta}(\sigma_\eta^2 - \sigma_\epsilon^2)}{2\sigma_\eta^2} + \frac{1}{2}\sqrt{\frac{(\sigma_\eta^2 + \sigma_\epsilon^2)(4\sigma_\eta^2 + \bar{\eta}^2(\sigma_\eta^2 + \sigma_\epsilon^2))}{\sigma_\eta^4}}}_{:=B}. \qquad (21)
$$

Checking for the second-order condition yields

$$
\frac{\partial^2 \Pi(h^0)}{\partial h^2} = \underbrace{e^{\frac{\bar{\eta}(y^* - \bar{\eta}) - \sigma_\eta^2}{2\sigma_\eta^2}} \frac{\sigma_\epsilon^4 \left(\bar{\eta}(y^* - \bar{\eta}) - \sigma_\eta^2\right)^4}{2\sqrt{2\pi}\sigma_\eta^2 (y^* - \bar{\eta})^6}}_{>0} \sqrt{-\underbrace{\frac{(y^* - \bar{\eta})^2 \sigma_\eta^2}{\bar{\eta}(y^* - \bar{\eta}) - \sigma_\eta^2}}_{<0 \text{ from (21)}}} > 0. \qquad (22)
$$

Hence, if $h^0 \in (0, 1)$ exists, it is a local minimum. Note that the expression under the square root in (22) is never negative if (21) holds.[25] This establishes that h^0 is the unique local extreme point, a minimum, iff $A < y^* < B$, where

$$
A := \frac{1}{2}(\bar{\eta} + \sqrt{\bar{\eta}^2 + 4\sigma_\eta^2})
$$

[25] Calculating $\frac{\delta^2 V(h)}{\delta h^2}$ and substituting for h^0 is straightforward. However, the expression is lengthy and reveals no additional insight. We therefore omit its exposition here. The derivation is available upon request.

and

$$B := \frac{\bar{\eta}(\sigma_\eta^2 - \sigma_\epsilon^2)}{2\sigma_\eta^2} + \frac{1}{2}\sqrt{\frac{(\sigma_\eta^2 + \sigma_\epsilon^2)(4\sigma_\eta^2 + \bar{\eta}^2(\sigma_\eta^2 + \sigma_\epsilon^2))}{\sigma_\eta^4}}.$$

■

Lemma 4 *On $h \in [0,1]$, if $y^* \geq B$, the incumbent's profit Π has a* ***global maximum****, which is $h^* = 1$, whereas if $y^* \leq A$, the* ***global maximum*** *is $h^* = 0$.*

Proof. Recall that in (18) the term $\bar{\eta}\sigma_y^2(y^* - \bar{\eta}) + \sigma_\eta^2 \left((y^* - \bar{\eta})^2 - \sigma_y^2\right)$ alone determines the algebraic sign of the derivative, because the other terms are positive. It is straightforward to show that

$$\frac{\partial \Pi(h)}{\partial h} > 0 \text{ on } h \in [0,1] \text{ if } y^* \geq B$$

and

$$\frac{\partial \Pi(h)}{\partial h} < 0 \text{ on } h \in [0,1] \text{ if } y^* \leq A.$$

Hence, the incumbent's optimal strategy is attained at the boundaries: $h^* = 1$ if $y^* \geq B$ and $h^* = 0$ if $y^* \leq A$. This establishes the lemma. ■

Lemma 5 *On $h \in [0,1]$, if $A < y^* < B$, a unique cutoff $\hat{y}$ exists such that if $y^* > \hat{y}$ then $h^* = 1$, whereas if $y^* < \hat{y}$ then $h^* = 0$, and if $y^* = \hat{y}$ the incumbent is indifferent between $h^* = 1$ and $h^* = 0$.*

Proof. From *Lemma 3* it is known that if the conjectured entry threshold belongs to the interval $A < y^* < B$, a unique local minimum $h^0 \in (0,1)$ exists. This means that in this interval, the (global) maximum of V is attained on the boundaries $h^* = 0$ or $h^* = 1$. We prove the existence and uniqueness of $\hat{y}$ by examining the behavior of the difference in the incumbent's profits at the boundaries, $\Pi(y^* \mid h = 0)$ and $\Pi(y^* \mid h = 1)$.

Define $\Delta\Pi(y^*) = \Pi(y^* \mid h = 1) - \Pi(y^* \mid h = 0)$. Note that $\hat{y}$ solves $\Delta\Pi(y^*) = 0$, which cannot be done explicitly since no closed-form solution for $\hat{y}$ exists. We therefore apply the intermediate value theorem to establish the lemma.

Clearly, $\Delta\Pi(A) < 0$ and $\Delta\Pi(B) > 0$ from *Lemma 3*. Therefore, according to the intermediate value theorem, the continuous function $\Delta\Pi(y^*)$ must have at least one zero on $[A, B]$. Since $\frac{\partial \Delta\Pi(y^*)}{\partial y^*} > 0$ for all $y^* \in [A, B]$ (which we prove below), it follows that $\Delta\Pi(y^*)$ has a unique zero.

First, differentiating $\Delta\Pi(y^*)$ with respect to y^* yields

$$\frac{\partial \Delta\Pi(y^*)}{\partial y^*} = \delta_I \left(f(y^* \mid h = 1)y^* - f(y^* \mid h = 0)\right) \frac{\bar{\eta}\sigma_\epsilon^2 + y^*\sigma_\eta^2}{\sigma_\epsilon^2 + \sigma_\eta^2},$$

and therefore proving $\frac{\partial \Delta\Pi(y^*)}{\partial y^*} > 0$ on $[A, B]$ is equivalent to proving

$$\frac{f(y^* \mid h=1)}{f(y^* \mid h=0)} \frac{y^*}{\frac{\bar{\eta}\sigma_\epsilon^2 + y^*\sigma_\eta^2}{\sigma_\epsilon^2+\sigma_\eta^2}} = e^{-\frac{(y^*-\bar{\eta})^2\sigma_\epsilon^2}{2\sigma_\eta^2(\sigma_\epsilon^2+\sigma_\eta^2)}} \frac{y^*(\sigma_\epsilon^2+\sigma_\eta^2)^{\frac{3}{2}}}{\sigma_\eta\left(\bar{\eta}\sigma_\epsilon^2 + y^*\sigma_\eta^2\right)} > 1.$$

The solution is found by recognizing that e^{-x} is an upper bound of $\frac{1}{(x+1)^2}$ on $x \in [0, 2]$ and observing that $0 \leq \frac{(y^*-\bar{\eta})^2\sigma_\epsilon^2}{2\sigma_\eta^2(\sigma_\epsilon^2+\sigma_\eta^2)} \leq 2$ for $y^* \in [A, B]$. Then, for $y^* \in [A, B]$,

$$\begin{aligned} e^{-\frac{(y^*-\bar{\eta})^2\sigma_\epsilon^2}{2\sigma_\eta^2(\sigma_\epsilon^2+\sigma_\eta^2)}} \frac{y^*(\sigma_\epsilon^2+\sigma_\eta^2)^{\frac{3}{2}}}{\sigma_\eta\left(\bar{\eta}\sigma_\epsilon^2 + y^*\sigma_\eta^2\right)} &> \frac{1}{\left(\frac{(y^*-\bar{\eta})^2\sigma_\epsilon^2}{2\sigma_\eta^2(\sigma_\epsilon^2+\sigma_\eta^2)}+1\right)^2} \frac{y^*(\sigma_\epsilon^2+\sigma_\eta^2)^{\frac{3}{2}}}{\sigma_\eta\left(\bar{\eta}\sigma_\epsilon^2 + y^*\sigma_\eta^2\right)} \\ = \frac{4y^*\sigma_\eta^3\left(\sigma_\epsilon^2+\sigma_\eta^2\right)^{\frac{7}{2}}}{\left(\bar{\eta}\sigma_\epsilon^2 + y^*\sigma_\eta^2\right)\left((y^*-\bar{\eta})^2\sigma_\epsilon^2 + 2\sigma_\epsilon^2\sigma_\eta^2 + 2\sigma_\eta^4\right)^2} &> \frac{4\sigma_\eta^3\left(\sigma_\epsilon^2+\sigma_\eta^2\right)^{\frac{5}{2}}}{\left((y^*-\bar{\eta})^2\sigma_\epsilon^2 + 2\sigma_\epsilon^2\sigma_\eta^2 + 2\sigma_\eta^4\right)^2} > 1, \end{aligned}$$

where the second line follows from using $y^* > \bar{\eta}$ and the third from (3) after some lines of algebra. As a consequence, a unique solution $\hat{y} \in (A, B)$ exists such that $\Delta\Pi(\hat{y}) = 0$. Hence, if $y^* > \hat{y}$ then $h^* = 1$, whereas if $y^* < \hat{y}$ then $h^* = 0$. By definition, $y^* = \hat{y}$ leaves the incumbent indifferent between $h^* = 1$ and $h^* = 0$. This establishes the lemma. ■

A.4 A Formal Investigation of the Probability and Information Effects

The first expression of (13), the Probability Effect, is *positive* as

$$-\frac{\partial(1 - F(y^* \mid h))}{\partial h} = \frac{(y^* - \bar{\eta})\sigma_\epsilon^2}{2\sigma_y^2} f(y^* \mid h) > 0. \tag{23}$$

Here the important insight is that hedging decreases the probability of market entry.

The second part of (13), the Information Effect, reflects the effect of h on the conditional profit reduction in the second period given that y_1 is *exceeding* y^*. While the Probability Effect suggests the incumbent has incentives to fully hedge, the Information Effect works into the other direction.

From (13), the sign of the Information Effect (and therefore the overall sign of the derivative) obviously is contingent on $-\frac{f(y^*|h)}{1-F(y^*|h)}$ being increasing or decreasing in h. Applying the quotient rule

$$-\frac{\partial}{\partial h}\frac{f(y^* \mid h)}{(1 - F(y^* \mid h))} = \underbrace{\underbrace{-\frac{\frac{\partial}{\partial h}f(y^* \mid h)\,(1 - F(y^* \mid h))}{(1 - F(y^* \mid h))^2}}_{\text{(+/-)}} + \underbrace{\frac{\frac{\partial}{\partial h}(1 - F(y^* \mid h))\,f(y^* \mid h)}{(1 - F(y^* \mid h))^2}}_{\text{(-)}}}_{\text{(-)}} \tag{24}$$

and equation (23) (namely, $\frac{\partial(1-F(y^*|h))}{\partial h} < 0$) reveals the key for the Information Effect being increasing or decreasing is how the density $f(y^* \mid h)$ changes at the threshold level y^*. In fact, it is easily shown that the first expression is negative if $y^* > \bar{\eta}$ is sufficiently small (because $\frac{\partial}{\partial h} f(y^* \mid h) > 0$), but positive if $y^* > \bar{\eta}$ is sufficiently large ($\frac{\partial}{\partial h} f(y^* \mid h) < 0$) (see also Figure 2). For the latter case, we prove that the sign of (24) is negative.

Proof. Observe that $1 - F(y^* \mid h)$ in (24) cannot be represented in terms of elementary functions. The solution is found by recognizing an upper bound for $1 - F(y^* \mid h)$, namely

$$\frac{\sigma_y \; e^{-\frac{(y^* - \bar{\eta})^2}{2\sigma_y^2}}}{\sqrt{2\pi}\,(y^* - \bar{\eta})} > 1 - F(y^* \mid h), \text{ for } y^* > \bar{\eta}. \tag{25}$$

Then, substituting for this upper bound and using (19) yields

$$-\frac{\partial}{\partial h} \frac{f(y^* \mid h)}{(1 - F(y^* \mid h))} < -\sigma_\epsilon^2 \frac{\sigma_y \; e^{-\frac{(y^* - \bar{\eta})^2}{2\sigma_y^2}}}{4\pi\,(y^* - \bar{\eta})\,\sigma_y^2\,(1 - F(y^* \mid h))^2} < 0,$$

which verifies that $-\frac{\partial}{\partial h} \frac{f(y^* | h)}{(1 - F(y^* | h))} < 0$. ■

A.5 Proof of Proposition 1

A graphical illustration to the proof of the (a) and (b) parts of Proposition 1 is in Figure 3. It is easy to show that the best reaction curves of incumbent and entrant can cross only once. Recall from (8) that the reaction curve of the *entrant* is given by $y^* = \beta + \gamma(1 - h^*)$, where from (4) $\beta > 0$ and $\gamma > 0$. This implies that $h^* = 1 + \frac{\beta}{\gamma} - \frac{1}{\gamma} y^*$ is downward sloping. The pattern of the best response function of the *incumbent* – it is non-continuous and involves a *jump up* at $y^* = \hat{y}$, where $\hat{y} \in (A, B)$ – follows from *Lemma 2*. The mixed-strategy equilibrium – the (c) part of Proposition 1 – is easily derived. The incumbent is indifferent between playing $h^* = 1$ and $h^* = 0$ if $y^* = \hat{y}$. When the incumbent randomizes over these strategies, the induced outcome to the entrant corresponds to a lottery over the pure-strategy payoffs weighted by the probabilities with which $h^* = 0$ and $h^* = 1$ are being played. Hence, $p^* \in (0, 1)$ solves $(1 - \delta_R)\,(p^* E(\eta \mid \hat{y}, h^* = 1) + (1 - p^*) E(\eta \mid \hat{y}, h^* = 0)) = K$.

A.6 Proof of Proposition 2

By using (12) and (16), the incumbent's profit Π in the mandatory hedge disclosure regime is

$$\begin{aligned} \Pi(y^*(h), h) := \quad & \bar{\eta} - \delta_I \int_{y^*(h)}^{+\infty} E(\eta \mid y_1, h) f(y^*(h), h) dy_1 \\ = \quad & \bar{\eta} - (1 - F(y^*(h), h)) \times \delta_I \left(\bar{\eta} + \sigma_\eta^2 \frac{f(y^*(h), h)}{1 - F(y^*(h), h)} \right), \end{aligned}$$

where $F(y^*(h), h)$ denotes the probability of remaining monopolist and $\delta_I \left(\bar{\eta} + \sigma_\eta^2 \frac{f(y^*(h), h)}{1 - F(y^*(h), h)} \right)$ denotes the expected loss to the incumbent conditional on y_1 *exceeding* $y^*(h)$. Following the decomposition proposed in

(12), the total change in the monopoly rent $V(y^*(h), h)$ with respect to h can be disaggregated into

$$
\begin{aligned}
\frac{d\Pi(y^*(h),h)}{dh} &= \underbrace{\underbrace{\frac{d}{dh}\left(1-F(y^*(h),h)\right)}_{>0 \text{ (see Lemma 6 below)}}\left(-\underbrace{\delta_I\left(\bar{\eta}+\sigma_\eta^2\frac{f(y^*(h),h)}{1-F(y^*(h),h)}\right)}_{>0 \text{ from (3)}}\right)}_{\text{“Probability Effect” (-)}} \\
&\quad+\underbrace{\underbrace{\left(1-F(y^*(h),h)\right)}_{>0}\left(-\underbrace{\frac{d}{dh}\delta_I\left(\bar{\eta}+\sigma_\eta^2\frac{f(y^*(h),h)}{1-F(y^*(h),h)}\right)}_{>0 \text{ (see Lemma 7 below)}}\right)}_{\text{“Information Effect” (-)}}.
\end{aligned}
$$

Proposition 2 follows immediately from showing that $\frac{d\Pi(y^*(h),h)}{dh} < 0$ on $h \in [0,1]$. The proof involves two lemmas:

1. **Lemma 6:** *The probability of market entry strictly increases in the incumbent's hedging choice h; hence* $\frac{d(1-F(y^*(h),h))}{dh} > 0$.
2. **Lemma 7:** *The loss from market entry conditional on y_1 exceeding $y^*(h)$ strictly increases in the incumbent's hedging choice h; hence* $\frac{d}{dh}\delta_I\left(\bar{\eta}+\sigma_\eta^2\frac{f(y^*(h),h)}{1-F(y^*(h),h)}\right) > 0$.

Both lemmas can be established as follows.[26]

Lemma 6 *The probability of market entry strictly increases in the incumbent's hedging choice h; hence* $\frac{d(1-F(y^*(h),h))}{dh} > 0$.

Proof. Taking the total derivative of $1 - F(y^*(h), h)$ with respect to h yields

$$
\begin{aligned}
\frac{d\left(1-F(y^*(h),h)\right)}{dh} &= \underbrace{\frac{\partial\left(1-F(y^*(h),h)\right)}{\partial y^*(h)}\frac{dy^*(h)}{dh}}_{\text{“Strategic Effect”}}+\frac{\partial\left(1-F(y^*(h),h)\right)}{\partial h} \\
&= f(y^*(h),h)\left(\frac{\sigma_\epsilon^2}{\sigma_\eta^2}\left(\frac{K}{1-\delta_R}-\bar{\eta}\right)-\frac{(y^*(h)-\bar{\eta})\sigma_\epsilon^2}{2\sigma_y^2}\right) \\
&= f(y^*(h),h)\frac{\sigma_\epsilon^2}{\sigma_\eta^2}\underbrace{\left(\frac{K}{1-\delta_R}-\bar{\eta}\right)}_{>0 \text{ from (4)}}\left(1-\frac{1}{2}\right) > 0. \qquad (26)
\end{aligned}
$$

[26] In what follows, we omit the functional dependence of $f(\cdot)$ and $F(\cdot)$ on $y^*(h)$ and h for notational convenience where possible.

The first term in the first line reflects the incumbent's first-mover (i.e., Stackelberg leader) position. This "strategic effect" results from the influence of the hedging choice h on the entry threshold and does not exist in the earlier analysis of unobservable hedging activity. The second line follows from $\frac{\partial(1-F(y^*(h),h))}{\partial y^*(h)} = -f(y^*(h),h)$, $\frac{dy^*(h)}{dh} = -\frac{\sigma_\epsilon^2}{\sigma_\eta^2}\left(\frac{K}{1-\delta_R} - \bar{\eta}\right)$, and $\frac{\partial(1-F(y^*(h),h))}{\partial h} = -\frac{(y^*(h)-\bar{\eta})\sigma_\epsilon^2}{2\sigma_y^2} f(y^*(h),h)$, which follows along the lines from (23). The third line substitutes $y^*(h)$ from (15). ■

Lemma 7 *The loss from market entry conditional on y_1 exceeding $y^*(h)$ strictly increases in the incumbent's hedging choice h; hence $\frac{d}{dh}\delta_I\left(\bar{\eta} + \sigma_\eta^2 \frac{f(y^*(h),h)}{1-F(y^*(h),h)}\right) > 0$.*

Proof. Taking the total derivative of $\delta_I\left(\bar{\eta} + \sigma_\eta^2 \frac{f(y^*(h),h)}{1-F(y^*(h),h)}\right)$ with respect to h yields

$$\begin{aligned} & \frac{d}{dh}\delta_I\left(\bar{\eta} + \sigma_\eta^2 \frac{f(y^*(h),h)}{1-F(y^*(h),h)}\right) \\ = \; & \delta_I \sigma_\eta^2 \frac{\frac{df(y^*(h),h)}{dh}(1-F(\cdot)) - \frac{d(1-F(\cdot))}{dh} f(\cdot)}{(1-F(\cdot))^2} \end{aligned} \tag{27}$$

which is positive if the sign of the numerator is positive. The proof is lengthy and cannot be established easily because $\frac{d(1-F(\cdot))}{dh} > 0$, which has been derived in (26), and because

$$\begin{aligned} \frac{df(y^*(h),h)}{dh} &= \frac{\partial f(y^*(h),h)}{\partial y^*(h)}\frac{dy^*(h)}{dh} + \frac{\partial f(y^*(h),h)}{\partial h} \\ &= \left(\frac{(y^*(h)-\bar{\eta})}{\sigma_y^2} * \frac{\sigma_\epsilon^2}{\sigma_\eta^2}\left(\frac{K}{1-\delta_R} - \bar{\eta}\right) - \frac{\sigma_\epsilon^2\left((y^*(h)-\bar{\eta})^2 - \sigma_y^2\right)}{2\sigma_y^4}\right) f(\cdot) \\ &= \frac{\sigma_\epsilon^2\left(\sigma_\epsilon^2(1-h)(K-(1-\delta_R)\bar{\eta})^2 + \sigma_\eta^2(K-(1-\delta_R)\bar{\eta})^2 + \sigma_\eta^4(1-\delta_R)\right)}{2\sigma_\eta^4(1-\delta_R)^2\sigma_y^6} f(\cdot) > 0. \end{aligned}$$

Note that the second line follows from $\frac{\partial f(y^*(h),h)}{\partial y^*(h)} = -\frac{(y^*(h)-\bar{\eta})}{\sigma_y^2} f(y^*(h),h)$, $\frac{dy^*(h)}{dh} = -\frac{\sigma_\epsilon^2}{\sigma_\eta^2}\left(\frac{K}{1-\delta_R} - \bar{\eta}\right)$ and from using $\frac{\partial f(y^*(h),h)}{\partial h} = -\frac{\sigma_\epsilon^2\left((y^*(h)-\bar{\eta})^2-\sigma_y^2\right)}{2\sigma_y^4} f(y^*(h),h)$, which has been derived in (19). The third line follows from substituting for (15).

Recognizing that $\sqrt{\frac{2}{\pi}} \frac{e^{-\frac{1}{2}(\frac{y^*-\bar{\eta}}{\sigma_y})^2}}{(\frac{y^*-\bar{\eta}}{\sigma_y}) + \sqrt{(\frac{y^*-\bar{\eta}}{\sigma_y})^2+4}}$ is a lower bound for $1-F(y^*(h),h)$ (Abramowitz and Stegun, 1972, p. 298) and substituting $1-F(y^*(h),h)$ in (27) establishes the lemma. The proof follows the reasoning in A.2. The calculation is convoluted and reveals no additional insight. We therefore omit its exposition here. The derivation is available upon request. ■

A.7 Proof of Corollary 2

Proof. In a mandatory hedge disclosure regime, the entry threshold is given by

$$y_D^* = \frac{K}{1-\delta_R} + \frac{\sigma_\epsilon^2}{\sigma_\eta^2}\left(\frac{K}{1-\delta_R} - \bar{\eta}\right),$$

whereas the entry threshold in a non-disclosure regime under the parameter values of Proposition 1a is

$$y_{ND}^* = \frac{K}{1-\delta_R}.$$

Clearly, $y_D^* > y_{ND}^*$. Note that the probability of entry is given by $1 - \Phi\left(\frac{y_D^* - \bar{\eta}}{\sqrt{\sigma_\eta^2 + \sigma_\epsilon^2}}\right)$ and $1 - \Phi\left(\frac{y_{ND}^* - \bar{\eta}}{\sqrt{\sigma_\eta^2}}\right)$, respectively, where $\Phi(\cdot)$ denotes the cdf of the standard normal distribution. Observe that $\frac{\partial \Phi(x)}{\partial x} > 0$ for all x. Showing that $\frac{y_D^* - \bar{\eta}}{\sqrt{\sigma_\eta^2 + \sigma_\epsilon^2}} > \frac{y_{ND}^* - \bar{\eta}}{\sqrt{\sigma_\eta^2}}$ establishes the result. ■

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