Voluntary Disclosure with a Potential Competitor

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This paper analyzes a firm’s incentives to disclose private information of market demand and its own cost when there is a potential entrant into the market. Both market demand and incumbent’s production cost could be high or low. In such a situation, revelation of the state by the incumbent affects the entry decision. The model illustrates that there is a unique fully revealing disclosure equilibrium in which every type of incumbent, except the high demand-high cost type (the most favorable state for the entrant), is transparent. This result is mainly due to the strong incentive of the high demand-high cost type to be nontransparent in any equilibrium candidate in order to discourage entry. This keeps other types from being nontransparent so that they can prevent pooling with the high demand-high cost type. This result changes once costly auditing (information gathering) is introduced. When the auditing of transparent incumbents is costly and the entrant avoids it due to its high cost, there exist pooling and partially pooling equilibria. In such equilibria, the high demand-high cost type succeeds in hiding herself, though sometimes imperfectly, since the other types cannot credibly communicate their real states.

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A. Introduction

In today’s financial system, firms accessing capital markets are required to follow mandatory disclosure rules set by corresponding regulatory institutions like the Securities and Exchange Commission (SEC). In addition to this, some firms but not all make voluntary disclosures such as management forecasts, press releases, etc. This action makes sense when one takes into consideration the informational asymmetry existing between managers and other stakeholders about value-relevant firm related information. Thus, these voluntary disclosures could be aiming at minimizing the ‘lemons problem’ of Akerlof (1970) as much as possible. However, a puzzling empirical fact is that firms’ voluntary disclosure policies differ a lot in terms of the amount and types of disclosures supplied. While some firms are known for being transparent others are likely to be much more silent (Lang, 1998 and Watson et al., 2002). A challenging task for researchers is to determine and understand the underlying incentives behind these varying actions of voluntary disclosure.

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Several attempts have been made in different scenarios relating voluntary disclosure. This paper studies voluntary disclosure policy of an incumbent firm when there is a potential entrant into the market. The incumbent firm holds private information about the market demand and its own production cost. Both the market demand and incumbent’s production cost can be high or low. The incumbent can choose a different disclosure policy depending on the combination of the demand and its own cost state since the state she is in affects the entry probability of the entrant. While a high (low) market demand increases (decreases) the entry probability, a low (high) cost incumbent discourages (encourages) entry. However, the analysis shows that there exists a unique fully revealing disclosure equilibrium in which every type of the incumbent, except the high demand-high cost type, are transparent. The high demand-high cost type is indifferent between a transparent and nontransparent disclosure policy in this equilibrium. The key point behind this result is that the high demand-high cost type or the most favorable state from the viewpoint of the entrant is likely to be nontransparent in any equilibrium candidate. By committing to a nontransparent disclosure policy, the high demand-high cost type tries to decrease the entry probability. She would succeed in this attempt if any other type of incumbent, which is in a less favorable state for the entrant, also prefers to be nontransparent in equilibrium. However, it is not optimal for any other type of incumbent to be pooled with the high demand-high cost type. When they are nontransparent like the high demand-high cost type, this would lead to an increase in the entry probability of the entrant compared to the entry probability when they are transparent. Thus, all of the incumbent types disclose their private information in equilibrium due to the strong incentive of the high demand-high cost type to withhold information which leaves this type as indifferent at the end. Yet, the unique fully revealing equilibrium of the model reinforces the ‘paradox’ that empirically, while some firms are transparent, others prefer to stay silent.

The model is then extended to the situation of costly information gathering (auditing) to decipher the ‘paradox’. In such a scenario, there exists a costly processing and verification of the disclosed information. The entrant has to bear a fixed cost in order to discover the real type of a transparent incumbent. This fixed cost could be considered as the auditing cost of the management reports of the incumbent firm. The model with costly auditing yields no separating equilibrium when the cost of auditing is larger than the difference between the expected payoffs of the entrant with auditing and no auditing, which means the entrant does not pay for the costly auditing. In this case, there exist pooling and partially pooling equilibria. In pooling equilibria, the incumbent type with the most favorable information succeeds in hiding herself since the other types cannot credibly communicate their real states even when they are transparent as auditing is costly and the entrant avoids it. And, in a partially pooling equilibrium this type could also succeed in hiding herself, though imperfectly. Indeed, each type of incumbent is indifferent between a transparent and nontransparent disclosure policy. This equilibrium could explain the earlier mentioned ‘paradox’. It could be that the firms randomly determine their disclosure policy since they could not communicate their private information due to the high auditing costs. Although this could sound as a pessimistic result, as the disclosure policy is irrelevant, this could be true for opaque industry structures where obtaining any information is much more difficult. Related to this, Huang (2008) states that ‘Industrial sectors in the early stage of industry cycle, or those using complex production and organization technologies, usually produce less information, and thus, their stocks exhibit less informative returns.’. Or, it could be true for industries (countries) which have not adopted the international accounting stan-
The main contribution of this paper to the existing literature is, analyzing disclosure incentives of an incumbent firm when market demand (industry-wide) and cost (firm-specific) information co-exist. Although there has been extensive research about voluntary disclosure of demand or cost information in oligopoly markets, the simultaneous effect of demand and cost on voluntary disclosure has been neglected. These models study the optimal disclosure policy of either demand or cost information in Cournot or Bertrand competition settings. Their results change depending on the assumed competition structure. However, the main result of the full-disclosure equilibrium of the present model does not depend on any competition structure but is very general. Additionally, the previous models assume a binary decision of entry for the entrant. The entrant either enters or stays out depending on the disclosure decision of the incumbent. However, the current model assumes a random entry cost. The entrant enters into the market with some probability depending on her expected profit upon entry which is contingent on the information disclosed. This construction also avoids the necessity of assuming fixed proprietary costs which is common in similar models. Last but not least, the model considers the situation of costly processing and verification of disclosed information. In previous studies, the assumption of a costless verification mechanism is standard which also implies availability of costless information gathering. The second part of the paper reconsiders the model without this assumption.

The next section provides more detailed information regarding the earlier literature and restates the contributions of this paper.

B. Prior Research

The earliest studies on voluntary disclosure are Grossman (1981) and Milgrom (1981). They analyze disclosure policy when a firm is evaluated by the financial market. In this case, the only equilibrium is full disclosure. Afterward, the optimal disclosure of market demand or cost information has been extensively examined beginning with Vives (1984) and Gal-or (1985, 1986). The main results are disclosure of (concealing) market demand is optimal with Bertrand (Cournot) competition. Conversely, disclosure of (concealing) cost information is optimal with Cournot (Bertrand) competition.

Mostly related papers to the current one are Darrough and Stoughton (1990), Wagenhofer (1989), Hwang and Kirby (2000) and Pae (2002). Darrough and Stoughton (1990) considers an entry game like in this paper in which the incumbent holds private information only about market demand. Different than this paper, the incumbent is evaluated both by the entrant and financial market contingent on disclosed information. They assume binary entry decision for the entrant which is not the case in the current model. Wagenhofer (1989) deals with a similar problem but considers continuous private (market demand) information of the incumbent which is more general than binary information structure of Darrough and Stoughton (1990). Hwang and Kirby (2000) study a game
where firms in an oligopolistic market hold private information about their own cost levels and new entry to the market is also possible. Pae (2002) is the single paper which considers the disclosure of market demand and cost information simultaneously. He considers an incumbent firm which operates in the market as a monopolist and becomes privately informed about the market demand and its production cost in the first period. In the second period, a new firm which is uninformed enters to the market. The incumbent prefers to fully disclose its private information in equilibrium like in the current model. The reason behind this result is the inter-temporal incentives of the incumbent. By disclosing full information, the incumbent nullifies its self-defeating intertemporal incentives by which she tries to deceive the entrant about the real state. The present paper offers an alternative explanation for the full-disclosure equilibrium with a signalling game. As opposed Pae (2002) who is restricted to the case of Cournot competition, the results of this paper hold in a more general competitive market setup. Additionally, Pae (2002) assumes no entry cost for the entrant which implies the entrant always enters in the second period. This is also not the case in this model which assumes a random entry cost. All of these papers assume costless verification and information gathering of the disclosed information which is not assumed in the second part of the model.

C. The Model

The model is a one period Bayesian Game with incomplete information and signalling. There are two players, the incumbent and the entrant. The first player is an incumbent firm which holds a monopoly position in a product market. The second player is an entrant firm which is willing to enter into this market. In the beginning of the period, nature chooses the type of the incumbent. There are four possible types of incumbent that correspond to combinations of two different demand and cost levels. After observing her type, the incumbent determines her disclosure policy which can be disclosing the full state (both cost and demand state) or withholding the all information. The profit of the incumbent is affected by her disclosure policy through the potential entrant’s decision. While a high (low) market demand increases (decreases) the entry probability, a low (high) cost incumbent discourages (encourages) entry. On the other hand, the entrant disburses a random cost of $K$ to enter the market with continuous cumulative distribution function, $F(K)$. That means the entrant always enters into the market with some positive probability. An important assumption in this setting, the entrant becomes informed about the state once she enters the market even when the incumbent has chosen non-transparency.

The timeline of events is as follows: First, nature chooses the incumbent’s type. Then the incumbent determines her disclosure policy which can be either disclosing the full state or withholding the all information, after learning the state she is in. Thus, disclosure policy of the incumbent is a binary decision. The variable $t \in \{0, 1\}$ indicates the disclosure decision of the incumbent, with $t = 1$ standing for full disclosure. Following the incumbent’s move, the entrant learns his cost drawn from $F(K)$ and decides on her entry probability contingent on incumbent’s disclosure policy. Finally, payoffs realize in the product market. Figure 1 summarizes the timeline of events.
The states or the types of the incumbent are denoted by $\omega$ where $\omega \in \{1, 2, 3, 4\}$. Each state, from 1 to 4, occur with probabilities $\alpha, \beta, \theta$ and $\mu$ which are common knowledge. Type 1 corresponds to high demand, low cost state ($H_D, L_C$) whereas type 2 corresponds to high demand, high cost state ($H_D, H_C$). Similarly, type 3 refers to low demand, low cost state ($L_D, L_C$), whereas type 4 corresponds to low demand, high cost state ($L_D, H_C$). The profit of the incumbent in state $\omega$ is denoted $\pi_I(\omega)$ when the entrant enters and $\Pi(\omega)$, when she stays out. Here, $\Pi(\omega)$ refers to the monopoly profit in state $\omega$. The profit of the entrant in state $\omega$ is denoted $\pi_E(\omega)$, when she is in the market. It is clear that the monopoly profit is larger than the duopoly profit in $\omega$, $\Pi(\omega) > \pi_I(\omega)$. Additionally, it is possible to order monopoly (duopoly) profits in different states.

The best possible state for the incumbent is the high demand-low cost state $\omega = 1$ whereas, the worst possible state is low demand-high cost, $\omega = 4$. Thus, the monopoly and duopoly profits of the incumbent can be ordered as $\pi_I(1) \geq \pi_I(2) \geq \pi_I(4)$ ($\Pi(1) \geq \Pi(2) \geq \Pi(4)$) and $\pi_I(1) \geq \pi_I(3) \geq \pi_I(4)$ ($\Pi(1) \geq \Pi(3) \geq \Pi(4)$). However, it is not possible to make a comparison between $\pi_I(2)$ and $\pi_I(3)$ ($\Pi(2)$ and $\Pi(3)$). In a similar fashion, the profits of the entrant can be ordered as $\pi_E(2) \geq \pi_E(1) \geq \pi_E(3)$ and $\pi_E(2) \geq \pi_E(4) \geq \pi_E(3)$. The entrant benefits from a high demand state but suffers from a low-cost competitor. Thus, one cannot compare the profits of $\pi_E(1)$ and $\pi_E(4)$ like in the case of incumbent with $\pi_I(2)$ and $\pi_I(3)$. The complete ordering of incumbent’s and entrant’s profits depends on the marginal effects of cost and demand.

Both players are risk neutral and maximize their expected terminal payoff. That is to say, the incumbent decides on her disclosure policy to maximize her expected payoff and the entrant determines her entry probability such that she enters the market only if she obtains positive payoff.

Last but not least, an important assumption in the model is truthful and costless disclosure. It is reasonable to assume that firms truthfully disclose, especially if they are subject to auditing.

**D. Strategic Analysis**

**D.1. Disclosure Decision**

Backwards induction is used in order to determine the Perfect Bayesian-Nash equilibria of the game. First, the entry decision of the entrant in terms of probabilities is determined. The entrant knows the type of the incumbent with probability one when she encounters a transparent incumbent. In this situation, she enters into the market with probability $F(\pi_E(\omega))$ where $\omega \in \{1, 2, 3, 4\}$. Hence,
she enters only when her cost of entry is less than her payoff. On the other hand, the entrant forms posterior beliefs according to the Bayes’ rule in each information set where she encounters a non-transparent incumbent. The posterior beliefs are denoted by $q(\omega|t = 0)$ where $t = 0$ indicates a nontransparent disclosure policy. Now, the entrant enters into the market with probability $F(\sum_{\omega=1}^{4} q(\omega|t = 0)\pi_{E}(\omega))$. Accordingly, she takes into consideration her expected payoff after seeing a non-transparent incumbent and enters into the market when she obtains positive payoff.

Now turn to incumbent’s disclosure decision. Intuitively, the disclosure decision of the incumbent depends mainly on the entrant’s decision. When the entrant is more likely to enter, the incumbent is more likely to conceal information. This fact creates strong incentive for high demand-high cost type ($\omega = 2$) to choose a nontransparent policy. This is because the entrant can obtain the highest possible profit when the incumbent is of type 2. On the other hand, low demand-low cost type ($\omega = 3$) is the least likely type to prefer a nontransparent policy since it is not a profitable state for the entrant. This intuition is formalized in the following proposition.

**Proposition 1.** There exist a PBE where all types are transparent. In this equilibrium, only type 2 is indifferent between a transparent and nontransparent disclosure policy. The consistent equilibrium belief is $q(2|t = 0) = 1$.

**Proof.** We show that the proposed equilibrium strategies constitute best responses for each type under the equilibrium beliefs which are consistent with the equilibrium strategies.

For type 1 which is the high demand-low cost type the payoff of transparency must be at least as high as the payoff of nontransparency. This leads to the following inequality:

$$F(\pi_{E}(1))\pi_{I}(1) + (1 - F(\pi_{E}(1)))\Pi(1) \geq F(\pi_{E}(2))\pi_{I}(1) + (1 - F(\pi_{E}(2)))\Pi(1)$$

In this inequality, the entrant uses her equilibrium beliefs when she faces a nontransparent incumbent. The inequality becomes:

$$[F(\pi_{E}(2)) - F(\pi_{E}(1))]\Pi(1) \geq [F(\pi_{E}(2)) - F(\pi_{E}(1))]\pi_{I}(1)$$

It is clear that $\Pi(1) \geq \pi_{I}(1)$. That means eq.(2) always holds if $F(\pi_{E}(2)) \geq F(\pi_{E}(1)) \iff \pi_{E}(2) \geq \pi_{E}(1)$ which is actually the case.

A very similar argument holds for the other types. Type 2, which is high demand-high cost type, is indifferent between transparency and nontransparency that is,

$$F(\pi_{E}(2))\pi_{I}(2) + (1 - F(\pi_{E}(2)))\Pi(2) = F(\pi_{E}(2))\pi_{I}(2) + (1 - F(\pi_{E}(2)))\Pi(2)$$

The payoffs of transparent and nontransparent disclosure policies for type 2 are equal under the equilibrium beliefs.

Like type 1, low demand-low cost type ($\omega = 3$) also prefers transparency:

$$F(\pi_{E}(3))\pi_{I}(3) + (1 - F(\pi_{E}(3)))\Pi(3) \geq F(\pi_{E}(2))\pi_{I}(3) + (1 - F(\pi_{E}(2)))\Pi(3)$$

which leads to:

$$[F(\pi_{E}(2)) - F(\pi_{E}(3))]\Pi(3) \geq [F(\pi_{E}(2)) - F(\pi_{E}(3))]\pi_{I}(3)$$

6
which holds since $F(\pi_E(2)) \geq F(\pi_E(3)) \Leftrightarrow \pi_E(2) \geq \pi_E(3)$.

Finally, low demand-high cost type ($\omega = 4$) prefers transparency:

$$F(\pi_E(4)) \pi_I(4) + (1 - F(\pi_E(4))) \Pi(4) \geq F(\pi_E(2)) \pi_I(4) + (1 - F(\pi_E(2))) \Pi(4) \Rightarrow$$

$$[F(\pi_E(2)) - F(\pi_E(4))] \Pi(4) \geq [F(\pi_E(2)) - F(\pi_E(4))] \pi_I(4)$$

Eq. (7) holds since $F(\pi_E(2)) \geq F(\pi_E(4)) \Leftrightarrow \pi_E(2) \geq \pi_E(4)$. □

Proposition 1 shows the existence of a full disclosure equilibrium. Furthermore, the next proposition illustrates that this is the unique equilibrium of the game in pure strategies. The insight behind this result can be summarized as follows: Revealing her state is a dominant strategy for the low demand-low cost type ($\omega = 3$) since it is the least profitable state for the entrant. Conversely, high demand-high cost type ($\omega = 2$) would like to withhold the information especially when the other types are also nontransparent. By committing to a nontransparent disclosure policy, she tries to discourage the entry since it is the most promising state for the entrant. Anticipating this, the other types prevent to be pooled with the high demand-high cost type by disclosing their state. They prefer disclosure since getting pooled with the high demand-high cost type would lead to an increase in the entry probability compared to the one when they are transparent. Here, Proposition 2 follows.

**Proposition 2.** The equilibrium of Proposition 1 is the unique equilibrium in pure strategies.

**Proof.** In PBE the equilibrium beliefs need to be consistent with the equilibrium strategies. In other words, on the equilibrium path players hold the right beliefs. While keeping this in mind, one should also realize high demand-high cost type ($\omega = 2$) always weakly prefers to be nontransparent in any other equilibrium candidate. This is due to the fact that $F(\pi_E(2)) \geq F(\sum_{t=1}^{4} q(\omega|t = 0) \pi_E(\omega)) \Leftrightarrow \pi_E(2) \geq \sum_{t=1}^{4} q(\omega|t = 0) \pi_E(\omega)$.

On the other hand, low demand-low cost type ($\omega = 3$) always weakly prefers to be transparent since $F(\sum_{t=1}^{4} q(\omega|t = 0) \pi_E(\omega)) \geq F(\pi_E(3)) \Leftrightarrow \sum_{t=1}^{4} q(\omega|t = 0) \pi_E(\omega) \geq \pi_E(3)$.

With the above facts, there remain three equilibrium candidates except the one in proposition 1. These are that either one of the types 1 or 4 is nontransparent, and both 1 and 4 are nontransparent at the same time:

a) The equilibrium candidate in which high demand-low cost and high demand-high cost types ($\omega = 1$ and $\omega = 2$) are nontransparent cannot realize. In this equilibrium path, consistent posterior beliefs are: $q(1|t = 0) + q(2|t = 0) = 1$, $q(3|t = 0) = 0$ and $q(4|t = 0) = 0$. For $\omega = 1$, these beliefs imply $F(\pi_E(1)) < F(q(1|t = 0) \pi_E(1) + q(2|t = 0) \pi_E(2)) \Leftrightarrow \pi_E(1) < q(1|t = 0) \pi_E(1) + q(2|t = 0) \pi_E(2) \Leftrightarrow \pi_E(1) < \pi_E(2)$ . This inequality implies that payoff of a transparent policy is larger or equal than the payoff of a nontransparent policy for type 1. This contradicts the proposed equilibrium and the beliefs.

b) The same logic is true for the equilibrium candidate in which low demand-high cost and high demand-high cost types ($\omega = 4$ and $\omega = 2$) are nontransparent: In this case, the consistent posterior beliefs are $q(4|t = 0) + q(2|t = 0) = 1$, $q(3|t = 0) = 0$ and $q(1|t = 0) = 0$ which implies $F(\pi_E(4)) < F(q(4|t = 0) \pi_E(4) + q(2|t = 0) \pi_E(2)) \Leftrightarrow \pi_E(4) < q(4|t = 0) \pi_E(4) + q(2|t = 0) \pi_E(2) \Leftrightarrow \pi_E(4) < \pi_E(2)$ . Thus, type $\omega = 4$ prefers to be transparent which is a contradiction.
c) The last equilibrium candidate that requires inspection is where all three types, except 3, are nontransparent. The consistent beliefs are: $q(4|t = 0) + q(2|t = 0) + q(1|t = 0, D) = 1$ and $q(3|t = 0) = 0$. In this equilibrium, for types 1 and 4 the payoff of nontransparency should be larger or equal than the payoff of transparency:

$$F(\pi_E(4)) \geq F(q(4|t = 0)\pi_E(4) + q(2|t = 0)\pi_E(2) + q(1|t = 0)\pi_E(1))$$

$$\Leftrightarrow \pi_E(4) \geq q(4|t = 0)\pi_E(4) + q(2|t = 0)\pi_E(2) + q(1|t = 0)\pi_E(1)$$

and

$$F(\pi_E(1)) \geq F(q(4|t = 0)\pi_E(4) + q(2|t = 0)\pi_E(2) + q(1|t = 0)\pi_E(1))$$

$$\Leftrightarrow \pi_E(1) \geq q(4|t = 0)\pi_E(4) + q(2|t = 0)\pi_E(2) + q(1|t = 0)\pi_E(1)$$

Solving both inequalities simultaneously yields: $q(2|t = 0) \leq q(1|t = 0)\frac{\pi_E(4) - \pi_E(1)}{\pi_E(2) - \pi_E(4)}$ and $q(2|t = 0) \leq (1 - q(1|t = 0))\frac{\pi_E(1) - \pi_E(4)}{\pi_E(2) - \pi_E(4)}$. It is unclear whether $\pi_E(1) \geq \pi_E(4)$ or $\pi_E(4) \geq \pi_E(1)$. However, in either way it implies $q(2|t = 0) \leq 0$. So, the only plausible posterior probability (belief) distribution is $q(2|t = 0) = 0$ and $q(1|t = 0) + q(4|t = 0) = 1$ which is not consistent with the proposed equilibrium where all three types 1, 2 and 4 are nontransparent. ■

Up to now, the solution of the disclosure policy game has offered only one answer. According to the model, all types of firms prefer to be transparent. However, casual observation suggests that fully revealing equilibrium is not very common. This result reinforces the ‘paradox’ that empirically, while some firms are transparent, others prefer to stay silent. This unrealistic aspect leads to questioning of the assumptions of the model and the notion of disclosure. In the current model, disclosure has been considered public and easily available: if the firm is transparent, her type becomes public and understood by a third party. And auditing a firm comes with a cost. In such a scenario, there exists a costly processing and verification of the disclosed information. The entrant has to bear a fixed cost in order to discover the real type of a transparent incumbent. This fixed cost could be considered as the auditing cost of the management reports of the incumbent firm. Accordingly, the next section considers a similar model but with costly information gathering (auditing).

### E. Disclosure Decision with Costly Auditing

The basic idea of the model is the same as before except that the entrant decides whether to audit a transparent firm in order to discover its type. The cost of auditing is fixed and denoted by $C \geq 0$. This section only considers two types of incumbents denoted by $\omega \in \{H, L\}$. Here, $H$ and $L$ may be considered as the high and low demand states. This implies for the incumbent and the entrant that $\pi_I(H) \geq \pi_I(L)$ and $\pi_E(H) \geq \pi_E(L)$. The probability that type $H$ is in the market occurs with probability $\alpha$. With the remaining probability, $1 - \alpha$, type $L$ is in the market. First, the auditing decision of the entrant and then the incumbent’s disclosure strategy are determined by backwards induction.
E.1. Auditing Decision

After observing a transparent or a nontransparent incumbent, the entrant updates her beliefs as to which type of the incumbent she faces. Denote by \( p(\text{H}|t=1) \) her conditional probability of incumbent type \( H \) given transparency and \( q(\text{H}|t=0) \) her conditional probability of incumbent type \( H \) given nontransparency. Thus the entrant’s expected payoff from auditing is

\[
p(H|t=1) \int_0^{\pi_E(H)} (\pi_E(H) - s) dF(s) + (1 - p(H|t=1)) \int_0^{\pi_E(L)} (\pi_E(L) - s) dF(s) - C
\]

(10)

On the other hand, the expected payoff when she does not audit is

\[
\int_0^{p(H|t=1)\pi_E(H)+(1-p(H|t=1))\pi_E(L)} [p(H|t=1)\pi_E(H) + (1 - p(H|t=1))\pi_E(L) - s] dF(s)
\]

(11)

which can be written as,

\[
\int_0^{EP(t=1)} [EP(t = 1) - s] dF(s)
\]

(12)

where \( EP(t = 1) \) is the expected payoff of the entrant conditional on transparency. Thus, the entrant audits if and only if

\[
p(H|t=1) \int_0^{\pi_E(H)} (\pi_E(H) - s) dF(s) + (1 - p(H|t=1)) \int_0^{\pi_E(L)} (\pi_E(L) - s) dF(s) - \int_0^{EP(t=1)} [EP(t = 1) - s] dF(s) \geq C
\]

(13)

E.2. Incumbent’s Strategy

Denote by \( \sigma_\omega \) the probability that type-\( \omega \) incumbent is transparent where \( \omega \in \{H, L\} \). When the entrant audits, the probabilities \((\sigma^*_H, \sigma^*_L)\) represent an equilibrium if there are \( p^*(H|t=1) \) and \( q^*(H|t=0) \) such that for \( \omega \in \{H, L\} \)

\[
F(\pi_E(\omega))\pi_I(\omega)+(1-F(\pi_E(\omega)))\Pi(\omega) \geq F(EP(t = 0))\pi_I(\omega)+(1-F(EP(t = 0)))\Pi(\omega), \text{ whenever } \sigma^*_\omega > 0
\]

(14)

where \( EP(t = 0) = q^*(H|t=0)\pi_E(H) + (1 - q^*(H|t=0))\pi_E(L) \) and it is the expected profit of the entrant conditional on a nontransparent incumbent,

\[
q^*(H|t=0) = \frac{\alpha(1 - \sigma^*_H)}{\alpha(1 - \sigma^*_H) + (1-\alpha)(1-\sigma^*_L)}, \text{ whenever } \sigma^*_H + \sigma^*_L < 2
\]

(15)

and

\[
p^*(H|t=1) = \frac{\alpha\sigma^*_H}{\alpha\sigma^*_H + (1-\alpha)\sigma^*_L}, \text{ whenever } \sigma^*_H + \sigma^*_L > 0.
\]

(16)

Alternatively, when the entrant does not audit, the probabilities \((\sigma^*_H, \sigma^*_L)\) represent an equilibrium if there are \( p^*(H|t=1) \) and \( q^*(H|t=0) \) such that for \( \omega \in \{H, L\} \)

\[
F(EP(t = 1))\pi_I(\omega)+(1-F(EP(t = 1)))\Pi(\omega) \geq F(EP(t = 0))\pi_I(\omega)+(1-F(EP(t = 0)))\Pi(\omega), \text{ whenever } \sigma^*_\omega > 0
\]

(17)
where \( EP(t = 1) = p^*(H|t = 1)\pi_E(H) + (1 - p^*(H|t = 1))\pi_E(L) \), \( EP(t = 0) \) is as defined before, \( q^*(H|t = 0) \) and \( p^*(H|t = 1) \) are as in equations (15) and (16).

Equilibrium condition (14) satisfies that for given beliefs of the entrant, \( p^*(. \) and \( q^*(. \), the incumbent assigns positive probability to be transparent if the payoff of transparency (LHS) is larger or equal than the payoff of nontransparency (RHS) in order to maximize his profit. By (14), the incumbent takes into account her transparency policy decision on the entrants’ beliefs. The two other equilibrium requirements, (15) and (16) are that the entrant’s beliefs are consistent with Bayes’ rule whenever possible.

E.3. Equilibrium

This section determines the equilibria of the disclosure policy game with costly auditing. The model illustrates that the entrant audits whenever the expected benefit is larger than its cost. The model with costly auditing replicates the earlier result when the entrant audits. Since the entrant learns the actual types of the incumbents when she audits, the type with the unfavorable information from the viewpoint of the entrant is transparent and the type with the favorable information is partially transparent like before. The interesting case occurs when the entrant does not audit: in such a case, there can exist pooling and partially pooling equilibria. In pooling equilibria, disclosure policies of incumbents do not send any information to the entrant whereas in partially pooling equilibria they send imperfectly.

Proposition 3. Given that the auditing cost \( C \) is sufficiently small such that
\[
C \leq \bar{C} = \alpha\pi_E(H)[F(\pi_E(H)) - F(\pi_E(E))] + (1 - \alpha)\pi_E(L)[F(\pi_E(L)) - F(\pi_E(E))] - \alpha \int_{\pi_E(H)} \pi_E(H) sdF(s) + \int_{\pi_E(L)}^{a[\pi_E(H) - \pi_E(L)]} \pi_E(H) sdF(s)
\]
and the entrant audits, in equilibrium type \( H \) is partially transparent and type \( L \) is fully transparent. (Note that \( E\pi_E = \alpha\pi_E(H) + (1 - \alpha)\pi_E(L) \).)

Proof. In the case of auditing, for type \( H \) the payoff of being nontransparent is always larger or equal than the payoff of being transparent. This is due to the fact that \( F(\pi_E(H)) \geq F(EP(t = 0)) \) \( \Leftrightarrow \pi_E(H) \geq EP(t = 0) \). This implies in equilibrium, \( \sigma^*_H \leq 1 \) which means type \( H \) is nontransparent in the equilibrium with some positive probability. Thus, \( q^*(H|t = 0) > 0 \).

The implication for type \( L \) when \( q^*(H|t = 0) > 0 \) is \( F(\pi_E(L)) < F(EP(t = 0)) \Leftrightarrow \pi_E(L) < EP(t = 0) \). Thus, type \( L \) is fully transparent in equilibrium with \( \sigma^*_L = 1 \). In return, type \( H \) is indifferent between a transparent and nontransparent disclosure policy.

The auditing region is determined by equation (13) and the equilibrium strategies of the incumbents. Equation (13) can be restated by inserting the equilibrium strategy of type \( L \), \( \sigma^*_L = 1 \) as:
\[
\frac{\alpha\sigma^*_H}{\alpha\sigma^*_H + (1 - \alpha)} \int_{0}^{\pi_E(H)} (\pi_E(H) - s)dF(s) + \left( \frac{1 - \alpha}{\alpha\sigma^*_H + (1 - \alpha)} \right) \int_{0}^{\pi_E(L)} (\pi_E(L) - s)dF(s)
\]
\[
- \int_{0}^{EP(t = 1)} [EP(t = 1) - s]dF(s) \geq C
\]

(18)

where \( EP(t = 1) = \frac{\alpha\sigma^*_H}{\alpha\sigma^*_H + (1 - \alpha)}\pi_E(H) + \frac{1 - \alpha}{\alpha\sigma^*_H + (1 - \alpha)}\pi_E(L) \). Here, one knows that as type \( H \) is more likely to be transparent, the gain from auditing increases for the entrant. This implies that (LHS) of equation (18) increases in \( \sigma^*_H \). Thus, the upper boundary of the audit region is determined as \( \sigma^*_H \rightarrow 1 \). (LHS) of equation (18) approaches \( C < \bar{C} = \alpha\pi_E(H)[F(\pi_E(H)) - F(\pi_E(E))] + (1 - \alpha)\pi_E(L)[F(\pi_E(L)) - F(\pi_E(E))] - \alpha \int_{\pi_E(H)} \pi_E(H) sdF(s) + \int_{\pi_E(L)}^{a[\pi_E(H) - \pi_E(L)]} \pi_E(H) sdF(s) \) as \( \sigma^*_H \rightarrow 1 \).
Proposition 4. There exists no separating equilibrium when the entrant does not audit for sufficiently large values of \( C \) such that \( C \geq \hat{C} \). In any partial pooling equilibrium, \( \sigma^*_H = \sigma^*_L \). In the pooling equilibria in which both types are either fully transparent or nontransparent, the out-of equilibrium belief for type \( H \) is larger than the prior probability of hers, which is \( \alpha \).

Proof. In the case of no auditing, assume that there exists a separating equilibrium in which type \( \omega \) is transparent and type \( \omega' \) is nontransparent, \( \omega \) and \( \omega' \in \{H, L\} \). This implies for type \( \omega \), \( F(EP(t=1)) < F(EP(t=0)) \iff EP(t=1) < EP(t=0) \). On the other hand, for type \( \omega' \), it implies \( F(EP(t=1)) > F(EP(t=0)) \iff EP(t=1) > EP(t=0) \) which creates a contradiction with the previous implication.

In a pooling equilibrium where both types are nontransparent, the equilibrium condition (17) implies \( F(EP(t=0)) < F(EP(t=1)) \iff EP(t=0) < EP(t=1) \):

\[
q^*(H|t=0)\pi_E(H) + (1 - q^*(H|t=0))\pi_E(L) < p^*(H|t=1)\pi_E(H) + (1 - p^*(H|t=1))\pi_E(L) \tag{19}
\]

\[
[q^*(H|t=0) - p^*(H|t=1)]\pi_E(H) < [q^*(H|t=0) - p^*(H|t=1)]\pi_E(L) \tag{20}
\]

which implies \( q^*(H|t=0) < p^*(H|t=1) \) where \( q^*(H|t=0) \) is equal to \( \alpha \) by the Bayes rule when equilibrium strategies \( \sigma^*_0 \), \( \omega \in \{H, L\} \) are inserted. Thus, in the nontransparent pooling equilibrium the out-of-equilibrium belief is larger than the prior, \( p^*(H|t=1) > \alpha \).

On the other hand in a pooling equilibrium where both types are transparent, by the equilibrium condition (17) \( F(EP(t=0)) \geq F(EP(t=1)) \iff EP(t=0) \geq EP(t=1) \) which implies \( q^*(H|t=0) \geq p^*(H|t=1) \). Here, \( p^*(H|t=1) = \alpha \) with the equilibrium strategies \( \sigma^*_\omega = 1, \omega \in \{H, L\} \). Therefore, in the transparent pooling equilibrium the out-of-equilibrium belief is larger or equal to the prior, \( q^*(H|t=0) \geq \alpha \).

In a partial pooling equilibrium in which \( 0 < \sigma^*_L < 1 \) and \( 0 < \sigma^*_H < 1 \), incumbents are indifferent between transparency and nontransparency which implies condition (17) holds with equality. This entails \( F(EP(t=0)) = F(EP(t=1)) \iff EP(t=0) = EP(t=1) \) which implies \( q^*(H|t=0) = p^*(H|t=1) \). Here, both \( q^*(H|t=0) \) and \( p^*(H|t=1) \) satisfy the Bayes’ rule in equations (15) and (16). Thus, the equation becomes,

\[
\frac{\alpha(1 - \sigma^*_H)}{\alpha(1 - \sigma^*_H)(1 - \alpha)(1 - \sigma^*_L)} = \frac{\alpha \sigma^*_L}{\alpha \sigma^*_H(1 - \alpha)\sigma^*_L} \tag{21}
\]

which holds whenever \( \sigma^*_L = \sigma^*_H \).

The boundary of the non-audit region is determined by inserting the equilibrium strategies of incumbents into equation (13) as before. For any partially pooling equilibria in which \( \sigma^*_L = \sigma^*_H \), LHS of equation (13) becomes equal to \( \hat{C} = \alpha \pi_E(H) [F(\pi_E(H)) - F(E\pi_E)] + (1-\alpha)\pi_E(L) [F(\pi_E(L)) - F(E\pi_E)] - \alpha \int_{\pi_E(H)}^{\pi_E(L)} F(s) \, ds + \int_{0}^{\alpha \pi_E(L) - \pi_E(L)} F(s) \, ds \). That is also the case for the pooling equilibria.

The model with costly auditing remedies the earlier model by offering possible other equilibria types additional to the fully revealing one which arises again when the entrant audits. Especially, the partially pooling equilibrium could characterize the empirical fact that some firms voluntarily disclose more than others which are usually silent. In this equilibrium, each type of incumbent is indifferent between a transparent and nontransparent disclosure policy. The earlier mentioned empirical fact could stem from this randomness. Thus, the firms randomly determine their disclosure policy since they could not communicate their private information due to the high auditing costs. In pooling and
partially pooling equilibria, the type with the most favorable information for the entrant succeeds in hiding herself, though sometimes imperfectly, since the other types cannot credibly communicate their real states. Although the model with costly auditing has considered two types of incumbents, one can show that the obtained equilibria will endure with the earlier four typed structure with respect to both demand and cost level.

E.3.1. Multiple Equilibria and Equilibrium Selection

The previous section provides multiple equilibria when the entrant does not audit. Multiple equilibria arise in signalling games because PBE does not restrict the Receiver’s response to signals that are sent with zero probability in equilibrium. In other words, PBE does not confine out-of-equilibrium beliefs (Sobel, 2004). Over the years, different refinements were introduced in order to deal with this issue. These refinements aim to restrict the meaning of unsent signals. One of the effective refinements is condition D1 introduced in Cho and Kreps (1987). Condition D1 is less restrictive than the condition of universal divinity introduced in Banks and Sobel (1987). In this respect, the number of equilibria of the previous section when the entrant does not audit due to high auditing cost, can be reduced by employing this concept of divinity.

Given an equilibrium \((\mu^*(s,a), \sigma^*(\tau,s))\) where \(\mu^*(s,a)\) is the system of behavior strategies of the receiver taking action \(a\) following the signal \(s\) and \(\sigma^*(\tau,s)\) is the system of behavior strategies of the sender-type \(\tau\) sending signal \(s\). Let \(U^*(\tau)\) be the equilibrium expected payoff of a type \(\tau\) sender and \(\beta^*(\tau,s)\) be the equilibrium beliefs. In this paper, signal \(s\) is the transparency choice, action \(a\) is the auditing choice and types of the incumbent are \(\tau \in \{H, L\}\). Additionally, define \(D(\tau,s) = \{a : u(\tau,s,a) \geq U^*(\tau)\}\) where \(u(\tau,s,a)\) is any out-of-equilibrium payoff. \(D(\tau,s)\) is the set of pure-strategy responses to out-of-equilibrium signal \(s\) that provide payoffs at least as large as the equilibrium payoff of player \(\tau\).

Divinity by Banks and Sobel (1987) requires that if \(D(\tau,s)\) is properly contained in \(D(\tau',s)\) then it should be the case that \(\beta^*(\tau,s) \geq \alpha^*(\tau)\) where \(\alpha^*(\cdot)\) is the prior probabilities over types \(\tau\). This refinement aims to increase the relative probability of the types which are more likely to deviate from the equilibrium. By this refinement, when the receiver observes a deviation she believes that the deviator is more likely to be type \(\tau'\).

Given the pooling equilibrium where both types are non-transparent when the entrant does not audit, \(U^*(H) = F(\alpha_\pi_E(H) + (1 - \alpha)\pi_E(L))\pi_I(H) + (1 - F(\alpha_\pi_E(H) + (1 - \alpha)\pi_E(L)))\pi_I(L)\) and \(U^*(L) = F(\alpha_\pi_E(H) + (1 - \alpha)\pi_E(L))\pi_I(L) + (1 - F(\alpha_\pi_E(H) + (1 - \alpha)\pi_E(L)))\pi_I(L)\). In this equilibrium\(^2\),

\[
D(t = 1, L) = \{\text{audit : } u(L, t = 1, \text{audit}) \geq U^*(L), \text{no – audit : } u(L, t = 1, \text{no – audit}) \geq U^*(L)\}\]

and

\[
D(t = 1, H) = \{\text{no – audit : } u(H, t = 1, \text{no – audit}) \geq U^*(H)\}\]

where \(t = 1\) represents a transparent policy. Accordingly, \(D(t = 1, H)\) is strictly contained in \(D(t = 1, L)\). Divinity requires that \(\beta^*(L, t = 1) = \binom{p(H|t = 1)}{p(H|t = 1)} \geq \frac{\alpha^*(L)}{\alpha^*(H)} = \frac{1 - \alpha}{\alpha}\) which implies \(p(H|t = 1) \leq \alpha\). However, in the equilibrium the out-of-equilibrium belief \(p^*(H|t = 1)\) should be larger than the prior, \(\alpha\). That is to say, the pooling equilibrium with non-transparent incumbents fail to satisfy the refinement of divinity.

\(^2\)Here, no-audit action of the receiver is written as weakly because the payoff \(u(\tau, t = 1, \text{no – audit})\) will be larger or equal than the equilibrium payoff \(U^*(\tau)\) depending on the beliefs held at the out-of-equilibrium path.
In contrast, given the pooling equilibrium where both types are transparent when the entrant does not audit,

\[ U^*(H) = F(\alpha \pi_E(H) + (1 - \alpha)\pi_E(L))\pi_I(H) + (1 - F(\alpha \pi_E(H) + (1 - \alpha)\pi_E(L)))\Pi(H) \]

and

\[ U^*(L) = F(\alpha \pi_E(H) + (1 - \alpha)\pi_E(L))\pi_I(L) + (1 - F(\alpha \pi_E(H) + (1 - \alpha)\pi_E(L)))\Pi(L) \]

In this equilibrium,

\[ D(t = 0, L) = \{\text{no - audit} : u(L, t = 0, \text{no - audit}) \geq U^*(L)\} \]

and

\[ D(t = 0, H) = \{\text{no - audit} : u(H, t = 0, \text{no - audit}) \geq U^*(H)\} \]

where \( t = 0 \) represents a non-transparent policy. Since neither of the \( D(t = 0,.) \) sets are strictly contained in the other one, divinity does not apply to this pooling equilibrium. It is also noteworthy that this pooling equilibrium where both incumbents are transparent, is robust to index theory.

Consequently, divinity refinement eliminates the pooling equilibrium in which both incumbent types are nontransparent. On the other hand, the pooling equilibrium in which they are transparent is robust to this refinement.

**F. Conclusion**

This paper examines a firm’s incentives to disclose private information of market demand and its own cost when there is a potential entrant into the market. When costless auditing is assumed which means the entrant comprehends the type of a transparent incumbent instantly, there is a unique equilibrium in which all types, except the high demand-high cost type (the most favorable information for the entrant), are fully transparent. This result changes once costly auditing is introduced. When the auditing of transparent incumbents is costly and the entrant avoids it due to its high cost, there exist pooling and partially pooling equilibria. In such equilibria, the type with the most favorable information succeeds in hiding herself, though sometimes imperfectly, since the other types cannot credibly communicate their real states. One of the pooling equilibria in which each type is nontransparent, fail to satisfy the Divinity refinement of Banks and Sobel (1987). The model with the costly auditing could be considered as more realistic especially for opaque industry structures or accounting standards. The partially pooling equilibria when the entrant does not audit could characterize the empirical fact and the casual observation that while some firms disclose others stay quiet.
G. References


