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DELEGATING DISCLOSURE AND CONTROL*

by

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Abstract: We study the joint delegation of operating and disclosure choices in a multiprincipal agent setting. We find that joint delegation alters both the incentives to deviate from profit–maximizing operating choices and disclosure policy adoption choices. Incentive weights on revenues are greater for the firm with greater *ex ante* cost uncertainty, greater expected market size and greater expected profit margins. Further, relative to no delegation, joint delegation biases the disclosure choice away from disclosing information about the firm's own costs and toward disclosing information that helps the rival better understand its costs for the firm opting to place greater incentive weight on revenues. The bias is reversed for the firm choosing smaller incentive weights. Thus, our analysis suggests that the market receives more information about the cost structure of firms with smaller expected profit margins, market sizes and *ex ante* cost uncertainty and less information about the cost structure of firms with larger expected margins, market sizes and *ex ante* cost uncertainty.

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1. Introduction.

One of the most important characteristics of the modern firm is the separation of ownership and control and the associated requirement that decisions be delegated to "managers." The problems associated with the need to delegate (*e.g.*, agency costs) have received significant attention in the accounting, economics and finance literatures, usually using a single principal–agent framework.[1] Interestingly, when the literature turned to an analysis with more than one principal, benefits to delegation appeared.[2] In particular, Brander and Lewis [1986], Fershtman and Judd [1987], Sklivas [1987] and Hermalin [1994] demonstrated that owners could benefit from delegating control of the firm's strategic responses to its rivals to a manager. In essence, the contractual delegation of control serves as a pre–commitment device allowing the owners of firms an opportunity to obtain a competitive advantage over their rivals when competing in their product markets. More recent contributions focus on the effect of contractual observability and provide two main results. First, even in the absence of observability, owners benefit from delegation. Second, if contracts are observable and owners can offer contracts that depend on the profits earned by all of the rivals in the industry, collusive outcomes can be supported.[3] In an important extension, Hughes and Williams [2008] examine owners' incentives to *voluntarily* disclose the contractual arrangements with their managers. Their key results are that, absent costs of disclosing, firms voluntarily disclose their contractual arrangements and continue to do so if the costs of disclosure are small enough. They also show that the the firms continue to disclose if the non–strategic benefits of such commitments are large or if owners have access to enough different commitment mechanisms.

Separation of ownership and control also means that the decision to disclose private information is delegated to the firm's manager as well. The objective of this paper is to analyze how delegating both the operating and disclosure decisions to a manager affects both the equilibrium incentives offered to the manager and the equilibrium decision to adopt or not adopt a policy of disclosing market–relevant information (*i.e.*, information about customers or production costs. Prior work on disclosure policy (*e.g.*, Gal–Or 1985, 1986, Darrough 1993, Raith 1996 or the nice summary in Vives 2008) abstracts from the effects of delegation (*i.e.*, assumes that the manager's

[1] There is a voluminous literature employing Principal–Agent models that is too large to cite exhaustively. Classic papers in this literature include Holmstrom [1979], Grossman and Hart [1983], Holmstrom and Milgrom [1987]. See also textbook treatments such as Laffont and Martimort [2001], Bolton and Dewatripont [2004] or Salanie [2005].

[2] See Gal–Or [1997] for an excellent survey of the literature on multiprincipal agency relationships.

[3] See Fershtman, Judd and Kalai [1991], Katz [1991], Fershtman and Kalai [1997], Hughes and Kao [1997], Kockesen and Ok [2004], Katz [2006], Kockensen [2007], or Manasakis et al. [2010] among others.

and owner's incentives are perfectly aligned) and focuses on the firm's willingness to disclose private information about its own operations (referred to as the private or independent values case) or market information that affects the payoffs of both firms equally (referred to as the common values case).[4] The central result in this literature is that the firms' decisions to adopt a policy of disclosing private information depends on whether the private information is about customers or costs and on whether the firms are Cournot or Bertrand competitors.[5]

We extend these literatures by examining the joint delegation of operating decisions and disclosure policy adoption choices. We find that joint delegation modifies the benefits from delegating operating decisions alone. Owners continue to delegate operating decisions in an attempt to shift sales and profits toward their firm and away from their rival, but the incentive weights that they choose do, however, depend on the delegated disclosure policy which, in turn, is affected by the delegation of operating decisions. In particular, when compared to disclosure policy adoption in the absence of delegation, we find that owners of firms who place greater incentive weight on revenues bias their managers' disclosure choices away from disclosing information predominantly about their firms' own costs and toward disclosing information that helps their rival managers better understand their own costs. The owners of firms who place less incentive weight on revenues bias their managers' disclosure choices in the opposite way—toward disclosing information about their own firms' costs and away from disclosing information that helps their rivals better understand their own costs. In net, owners who delegate and place greater incentive weight on revenues increase the likelihood of their managers disclosing information about costs and reduce the likelihood of the rival managers disclosing information about costs. Interestingly, delegation does not affect the managers' incentives to disclose private information about customers in our model.

We also show that the owners choose a larger incentive weight on revenues if the firm's expected profit potential (equivalent in our model to expected profit margin), expected market share or prior cost uncertainty is greater than its rival's. In each of these cases, as mentioned above, the larger incentive weight is associated with both a greater likelihood of disclosure and a bias away

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[4] Raith [1996] extends the analysis in Gal–Or and Darrough by introducing imperfect signals and shows that the firm's disclosure policy is affected by the quality of the signal and how correlated the firms' signals are.

[5] Some recent contributions examining incentives to adopt a policy of disclosing the firm's private information prior to learning it include Maleug and Tsutsui [1996] who examine *ex ante* disclosure of information about the slope of the market demand curve, Arya and Mittendorf [2007] who introduce third party information and study its impact on *ex ante* disclosure policy choices, Currarini and Feri [2007] who study *ex ante* disclosure choices by subsets of rivals and Bagnoli and Watts [2011] who study the firms' information acquisition decisions and how they are affected by their subsequent disclosure policy adoption decisions.

from disclosure of information predominantly about the firm's own costs and toward disclosure of information that helps the rival manager better understand her own costs. Thus, our analysis predicts that the market will be provided more information about the cost structure of firms with smaller expected profit margins, smaller expected market shares or less cost uncertainty. It also predicts that the market will be provided with less information about firms with greater expected profit margins, greater expected market shares or more cost uncertainty. Finally, our analysis of the effects of *ex ante* cost uncertainty suggests that firms with shorter histories and firms in industries where the price of important inputs is highly variable are less likely to provide voluntary disclosures.

While none of these predictions have been tested directly, some papers provide evidence consistent with them. For example, Verrecchia and Weber [2006] examine redactions in required filings and show that more competitive industries (as measured by the Herfindahl Index) redact less.[6] Li [2010] shows that the fraction of firms in an industry offering management forecasts of earnings (capital expenditures) is increasing in one measure of competition and declining in a second. These measures are derived from a factor analysis, and she interprets the first as competition from potential entrants and the latter as competition from current rivals. Li also shows that the effects are smaller for industry leaders, a result she suggests may be due to industry leaders facing less competition.[7] Karuna [2011] points out that the interpretation of Li's factors is difficult and instead examines the voluntary disclosure of research and development costs, number of employees and the firm's order backlog. He relates these voluntary disclosures to price–cost margins and market size. Karuna finds that these voluntary disclosures are greater for firms with larger price–cost margins and firms that compete in larger markets, consistent with the predictions from our model.

Our model is most closely related to the model in Theilen [2007] who considers competition in a homogeneous product market with private information about costs (the private values case). He shows that if the managers' pay could be reduced if revenues increase, it is possible to reverse the delegation result in Gal–Or [1985] and Darrough [1993]. If not, then the disclosure policy choice is unaffected by delegation. Our model differs from his in that we permit the managers of firms to

[6] On the other hand, Dedmand and Lennox [2009] examine redactions by private firms in the U.K., and find contrasting results: firms whose managers *perceive* their firm to be in more competitive environments redact more frequently. This suggests that sample selection (focusing on publicly traded firms only or private firms only) may obsure some of the empirical relations between industry competitiveness and disclosure choices.

[7] Neither of Li's measures of voluntary disclosure directly captures the disclosure of information about production costs since earnings depend on both the revenue side and the cost side of the firm and capital expenditures are fixed not variable costs.

sell heterogeneous products, and to have private information about costs or customers. Further, we do not restrict attention to the private values case. Finally, our results differ from Theilen's by developing the conditions under which delegation of operating decisions affects disclosure policy choices and how delegation of disclosure choice affects operating decisions.

Delegation and disclosure have also been studied in a single principal–agent setting by Dye [1985], Arya, Glover and Sunder [1998] and Gigler and Hemmer [2001] among others. Dye shows that managers who learn the realized value of their performance measure may not find it optimal to voluntarily disclose such information. Arya et al. show that the owner of the firm may find it useful to restrict disclosure of interim performance measures. Gigler and Hemmer show that an owner who chooses a more conservative accounting system will make less timely voluntary disclosures. By focusing on a multiprincipal–agent framework, our analysis complements these papers by showing how delegation of disclosure affects and is affected by the delegating of operating decisions.

The remainder of the paper is organized as follows. Section 2 contains a description of our model. Sections 3, 4, and 5 describe equilibrium in the final, second and first stages of the game, respectively. We describe our results on delegation of operating and disclosure choices in Section 6 and conclude in Section 7.

2. The Model.

To analyze the joint delegation of operating and disclosure choices in a multiprincipal agent setting, we introduce delegation into the extended information structure introduced in Bagnoli and Watts [2011] but otherwise retain essentially the same game structure used in the prior literature. In particular, two firms choose a disclosure policy prior to acquiring their private information. Subsequently, they follow their chosen disclosure policies and then compete in the product market. We augment this structure by assuming that, prior to choosing their disclosure policies, the firms are permitted to delegate both the decision to adopt a policy of disclosure and the subsequent strategic choices in the firms' product markets to their managers.

The formal description of our model is as follows. In the first stage of the game, the owners delegate future operational and disclosure choices to their manager. We follow the analysis in Fershtman and Judd [1987] and Sklivas [1987] which builds on an insight in Schelling [1960] and assume the owners of a firm motivate their manager's decisions by offering to pay her based on

the firm's realized profits and realized revenues.[8] In particular, we assume that the manager's compensation is proportional to:

$$\mathcal{P}_i = \pi_i + \lambda_i S_i \qquad i = 1, 2 \tag{1}$$

where π_i is firm i's realized profits and S_i is its realized sales and the owners of each firm select $\lambda_i \geq 0$ to maximize their expected profits.

In the second stage of the game, each manager selects her firm's disclosure policy. Let $d_i \in \{D, N\}$ be the disclosure policy chosen where D (N) represents the choice to adopt a policy of disclosure (not adopt a policy of disclosure). As is standard, we assume that each makes the disclosure policy choice without knowing the choice of its rival. The managers then learn their private information and follow their chosen disclosure policies. Consequently, each manager potentially has two sources of information: her private information and, if her rival adopts a policy of disclosure, the private information disclosed by her rival manager. If a manager/firm makes a disclosure, we assume that it is truthful. Finally, in the third stage of the game, after learning all of the available information, the firms compete in their product markets by having their managers choose how much of their product to sell (Cournot competition). Everything else, including the incentive contract the owners select to motivate their managers, is common knowledge.[9] The managers make the disclosure policy adoption decision and their output decisions to maximize their expected payoffs (*i.e.*, we assume that managers are risk neutral).

The above structure (except for the delegation decision) is the standard one used in this literature (*e.g.*, Gal–Or 1985, 1986, Darrough 1993, Raith 1996) but we will use the information assumptions in Bagnoli and Watts [2011]. Thus, a firm's private information is *either* a_i or c_i, for $i = 1, 2$, where the former is a demand parameter and the latter is a cost parameter. The demands for the firm's products are:

$$p_i = \gamma_{ii} a_i + \gamma_{ij} a_j - q_i - t q_j \qquad i = 1, 2 \tag{1}$$

[8] We obtain similar results if the manager is paid based on the firm's realized profits and cost reduction efforts.

[9] The observability of the contract is somewhat controversial. Assuming observability appears to be consistent with the SEC's 2006 decision to require "plain English" discussion of the key components of CEO compensation (http://www.sec.gov/news/press/2006/2006-123.htm). Further, in our setting, the modern corporation with the associated separation of ownership and control, it is natural to assume that it is observable that the decisions have been delegated. This more limited observability has been shown (Kockesen 2007) to produce benefits similar to the type arising with observable contracts. For these reasons, we adopt the assumption that the contracts themselves are observable.

with $1 \geq \gamma_{ii}, \gamma_{ij} \geq 0$ for $i = 1, 2$ and $1 > t > 0$ to ensure that the firms sell substitute products. There are no fixed costs and firm 1's (2's) marginal costs are $mc_i \equiv \delta_{11}c_1 + \delta_{12}c_2$ ($mc_j \equiv \delta_{21}c_1 + \delta_{22}c_2$).[10]

To complete the information structure, we assume that the firms and managers have common priors: all variables are drawn from known distributions with finite means and variances. We also assume that all (a_1, a_2, c_1 and c_2) are independent so that the distribution of a_j given (a_i, c_i) and the distribution of c_j given (a_i, c_i) are both independent of (a_i, c_i). To ensure interior solutions in the final stage of the game, we assume that the smallest value of the intercept parameter for each firm exceeds the largest value that firm's marginal costs can take on. We seek a Bayes–Nash equilibrium of the model and begin by solving the final stage of the game, when the firms compete in the product market.

3. Final Stage: Product Market Competition.

When the firms compete in their product markets, each firm's manager chooses the output that maximizes her expected payoff conditional on all of the information available to her. Thus, her decision depends on her own private information (a_i or c_i), the disclosure strategy chosen by her rival, d_j, the information the rival's strategy requires disclosing, and her own disclosure strategy, d_i. Thus, there are sixteen possible information sets for firm i which we will represent by ϕ_i.[11]

In particular, the manager of firm i solves $\max_{q_i} \mathrm{E}[\pi_i + \lambda_i S_i \mid \phi_i]$ which is equivalent to

$$\max_{q_i} \quad \mathrm{E}[(1+\lambda_i)(\gamma_{ii}a_i + \gamma_{ij}a_j - q_i - tq_j)q_i - (\delta_{ii}c_i + \delta_{ij}c_j)q_i \mid \phi_i].$$

The first order condition is

$$q_i = \mathrm{E}\big[\frac{1}{2}(\gamma_{ii}a_i + \gamma_{ij}a_j - tq_j) - \frac{1}{2(1+\lambda_i)}(\delta_{ii}c_i + \delta_{ij}c_j) \mid \phi_i\big].$$

The usual calculations yield the following Proposition that describes equilibrium quantity choices and payoffs to the managers in the last stage of our game.

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[10] The parameters $\gamma_{ii}, \gamma_{ij}, \delta_{ii}$ and δ_{ij} create a flexible information structure for the managers' private information that results in the private and common values structures previously analyzed in the literature becoming special cases. In particular, the private values information structure is represented by $\gamma_{11} = \gamma_{22} = 1$ and $\gamma_{12} = \gamma_{21} = 0$ or $\delta_{11} = \delta_{22} = 1$ and $\delta_{12} = \delta_{21} = 0$; and the common values information structure by $\gamma_{11} = \gamma_{22} = \gamma_{12} = \gamma_{21} = 1$ or $\delta_{11} = \delta_{22} = \delta_{12} = \delta_{21} = 1$.

[11] The sixteen possible information sets are found by crossing the alternative private information combinations $\{(a_1, a_2), (a_1, c_2), (c_1, a_2), (c_1, c_2)\}$ with the different combinations of disclosure strategies the firms chose prior to learning their private information $\{(D, D), (D, N), (N, D), (N, N)\}$.

Proposition 1: *If the firms are Cournot competitors, equilibrium quantities are*

$$
\begin{aligned}
q_i(D,D) &= \frac{(2\gamma_{ii} - t\gamma_{ji})a_i + (2\gamma_{ij} - t\gamma_{jj})a_j}{(4-t^2)} \\
&\quad - \frac{(2(1+\lambda_j)\delta_{ii} - t(1+\lambda_i)\delta_{ji})c_i + (2(1+\lambda_j)\delta_{ij} - t(1+\lambda_i)\delta_{jj})c_j}{(1+\lambda_i)(1+\lambda_j)(4-t^2)} \\
q_i(D,N) &= \frac{(2\gamma_{ii} - t\gamma_{ji})a_i + (2\gamma_{ij} - t\gamma_{jj})\mathrm{E}[a_j \mid \phi_i]}{(4-t^2)} \\
&\quad - \frac{(2(1+\lambda_j)\delta_{ii} - t(1+\lambda_i)\delta_{ji})c_i + 2(1+\lambda_j)\delta_{ij} + t(1+\lambda_i)\delta_{jj})\mathrm{E}[c_j \mid \phi_i]}{(1+\lambda_i)(1+\lambda_j)(4-t^2)} \\
q_i(N,D) &= (\gamma_{ii}/2)a_i + \frac{(2\gamma_{ij} - t\gamma_{jj})a_j}{(4-t^2)} - \frac{t(2\gamma_{ji} - t\gamma_{ii})\mathrm{E}[a_i \mid \phi_j]}{2(4-t^2)} - \frac{\delta_{ii}c_i}{2(1+\lambda_i)} \\
&\quad - \frac{2(2(1+\lambda_j)\delta_{ij} - t(1+\lambda_i)\delta_{jj})c_j + (2(1+\lambda_i)\delta_{ji} - t^2(1+\lambda_j)\delta_{ii})\mathrm{E}[c_i \mid \phi_j]}{(1+\lambda_i)(1+\lambda_j)(4-t^2)} \\
q_i(N,N) &= (\gamma_{ii}/2)a_i - \frac{t(2\gamma_{ji} - t\gamma_{ii})\mathrm{E}[a_i \mid \phi_j] - 2(2\gamma_{ij} - t\gamma_{jj})\mathrm{E}[a_j \mid \phi_i]}{2(4-t^2)} \\
&\quad + \frac{(2(1+\lambda_i)\delta_{ji} - t^2(1+\lambda_j)\delta_{ii})\mathrm{E}[c_i \mid \phi_j] - 2(2(1+\lambda_j)\delta_{ij} - t(1+\lambda_i)\delta_{jj})\mathrm{E}[c_j \mid \phi_i]}{2(1+\lambda_i)(1+\lambda_j)(4-t^2)}.
\end{aligned}
$$

Equilibrium payoffs to the managers in this stage of the game are proportional to $\mathcal{P}_i^C(d_i,d_j) = (1+\lambda_i)[q_i(d_i,d_j)]^2$ *for* $i = 1,2; j \neq i$.

The equilibrium quantities in Proposition 1 show the effect of delegation on product market competition as originally described in Fershtman and Judd [1987] and Sklivas [1987]. In equilibrium, firm i's output is increasing in λ_i and decreasing in λ_j. To see why, assume that only the owners of firm i motivate their manager by placing greater weight on sales. These incentives cause the manager to sell more than a profit–maximizing manager for every level of output by the rival. The rival manager, anticipating the effect of the incentives, finds it optimal to "accommodate" them by reducing the output she chooses. As a result, firm i's sales are larger and firm j's sales are smaller than they would be absent delegation. And, even though total output is greater than if both managers were simply maximizing profits, sufficient sales are shifted to firm i so that its profits actually increase. Intuitively, delegation is a means of precommiting the firm to greater output which shifts profits toward the firm. In equilibrium, rivalry causes both firms' owners to provide incentives that emphasize revenues as well as profits in order to bias each manager's output choice upward.

What is more interesting and relevant when we turn to our analysis of disclosure choices is that the effects described above appear to work by implicitly lowering the manager's perceived cost of

selling additional units of output even though the owners are using revenue–based incentives. This feature is due to the linearity of both the incentive contract and the firm's demand, which allows revenue incentives to operate "as if" the manager faces reduced marginal costs of additional output. This equivalence will have important ramifications when we analyze the delegated disclosure choice in the next section.[12]

Having determined equilibrium quantities chosen in the final stage of the game, we turn to the second stage and examine under what conditions the managers choose to commit to disclose.

4. Stage 2: Disclosure Choices.

The equilibrium quantities and payoffs described in Proposition 1 are conditional on each possible specification of both the managers' private information and their disclosure policy adoption decisions. To determine the managers' equilibrium disclosure policy adoption decisions, we turn to an analysis of their *ex ante* disclosure incentives. Proposition 1 provides the information needed to describe the Bayes–Nash equilibrium of the second stage of our game as the equilibrium of the associated normal form game whose payoffs are the expected profits computed for each commitment decision.

		Firm 2	
		D	N
Firm 1	D	$\mathrm{E}[\pi_1^C(D,D)], \mathrm{E}[\pi_2^C(D,D)]$	$\mathrm{E}[\pi_1^C(D,N)], \mathrm{E}[\pi_2^C(N,D)]$
	N	$\mathrm{E}[\pi_1^C(N,D)], \mathrm{E}[\pi_2^C(D,N)]$	$\mathrm{E}[\pi_1^C(N,N)], \mathrm{E}[\pi_2^C(N,N)]$

Given this, the main result of our analysis on delegated disclosure is presented in Theorem 1.

Theorem 1: *When the firms are Cournot competitors, disclosure of customer information is a dominant strategy for manager i $(i = 1, 2\ i \neq j)$ if*

$$\text{(C1)} \qquad (2\gamma_{ji}/t) < \gamma_{ii} \qquad \text{or} \qquad \left(\frac{2t}{8-t^2}\right)\gamma_{ji} > \gamma_{ii},$$

and disclosure of cost information is a dominant strategy for manager i if

$$\text{(C2)} \qquad \left(\frac{1+\lambda_1}{1+\lambda_2}\right)\left(\frac{2}{t}\right)\delta_{ji} < \delta_{ii} \qquad \text{or} \qquad \left(\frac{1+\lambda_1}{1+\lambda_2}\right)\left(\frac{2t}{8-t^2}\right)\delta_{ji} > \delta_{ii}.$$

[12] If either the contract were non–linear in revenue or the firm's market demand were non–linear, then the equivalence would disappear.

Theorem 1 highlights some important effects of delegating both disclosure and control to a manager. Focusing first on disclosing information about costs, Theorem 1 indicates that the directional effect of delegating disclosure depends on which firm's owners place greater emphasis on revenues. If both firms' owners place equal emphasis, delegating disclosure choices to their managers produces exactly the same disclosure decisions the owners would have chosen themselves. That is, if the two owners place the same emphasis on revenues in their managers' contracts, there are no additional agency costs or benefits associated with delegating the disclosure decision in addition to the control decision.

A key implication of condition (C2) in Theorem 1 is that the manager discloses her private information about costs only it is sufficiently asymmetrically useful to the two managers. In particular, she discloses if the information is particularly useful to her and not particularly useful to her rival (δ_{ii} is large and δ_{ji} is small) or vice versa. If her private information is more symmetrically useful to the two managers, she chooses not to adopt a policy of disclosure. This result follows from the fact that, in a Cournot game, output choices are strategic substitutes and expected payoffs are a convex function of output. The latter implies that the manager prefers greater variability in her equilibrium output choice. The former implies that output is more variable if the manager's information is asymmetrically useful to the two firms. Combined, these features ensure that the manager adopts a policy of disclosure only when her private information is sufficiently asymmetrically useful to the two firms.

In contrast, when the owners place different weights on revenues, delegation of the disclosure decision (in addition to the control decision) changes the firms' disclosure policies. For example, if the owners of firm i place greater emphasis on revenues than the owners of the rival firm ($\lambda_i > \lambda_j$), then the delegated disclosure policy choices differ from the profit–maximizing choices. Delegation biases a manager's disclosure away from disclosing private information that is more informative about her own firm's costs and toward disclosing information that is more informative about the rival's costs. Thus, delegation inhibits the disclosure of the manager's private information about her firm's costs.

Interestingly, the net effect of delegation is to increase the likelihood of manager i (the manager of the firm that places greater emphasis on revenues) adopting a policy of disclosure and decreases

the likelihood of the rival manager doing so.[13] Specifically, for the firm placing greater emphasis on revenues, the manager is more likely to disclose private information about costs if this information is relatively useful to her rival in reducing her uncertainty about her (the rival's) costs. But, the manager is also *less* likely to disclose private information that is predominantly useful to herself and not particularly useful to the rival manager. Intuitively, the disclosing manager benefits from increasing the variability in her equilibrium output as a function of her private information. If the information is disclosed, the rival can both tailor her own output to the information disclosed (the information effect) and better understand the disclosing manager's competitive response to both the information and the rival's output choice (the strategic effect). If the information is predominantly useful to the rival, the disclosure increases the variability of the rival's output choice and thus the variability of the disclosing manager's output choice — the information effect dominates. On the other hand, if the information is predominantly useful to the disclosing manager, variability is reduced because the strategic effect dominates the information effect. The reverse is true for the firm that places less emphasis on revenues.

We should also note that disclosure policy adoption decisions depend on how similar the products are that the firms sell. In particular, absent delegation, when the products are more homogeneous, the set of parameter values for which the manager adopts a policy of disclosure is larger. Said differently, managers of firms that use differentiation strategies are less likely to adopt policies of disclosure.

These differences produce differences in the impact of delegation of disclosure and control for firms adopting differentiation instead of cost leadership strategies. Again, if the owners of the firms place equal emphasis on revenues ($\lambda_i = \lambda_j$) there are no incremental effects because delegation has no effect in the first place. However, if the owners of firm i place greater emphasis on revenues, their manager is more likely to disclose with delegation and the effect is greater when the two firms' products are more homogeneous. Said differently, the impact of delegation is smaller for firms that adopt product differentiation rather than cost leadership strategies.[14]

Theorem 2 also provides the unusual result that delegation has no effect when the manager's

[13] To make this precise, let $(\delta_{ii}, \delta_{ji}) \in [0,1]x[0,1]$, and assume a uniform distribution with full support on the unit square. In this case, the probability of disclosure is greater when the area associated with disclosure is greater. Theorem 1 indicates that the area of the unit square representing pairs of δ_{ii}, δ_{ji} that lead the manager to adopt a policy of disclosure is greater than when the disclosure choice is made by the owners directly.

[14] These results follow directly from condition (C2) in Theorem 1.

private information is about her own firm's customers. In our case, this result is really due to the linearity of demand and incentives and not to delegation itself.[15] Thus, if the owners anticipate that their manager will have private information about the firm's own customers, obtaining the benefits of delegating operational decisions to the manager leaves the benefits and costs of adopting a policy of disclosure unchanged.[16]

Finally, we can compare our results to those that would obtain in the special cases analyzed originally by Gal–Or [1985,1986] and Darrough [1993]. Those papers consider the private values and common values cases which, for our model, involve imposing restrictions on the γ's and δ's. In particular, the private values information structure has $\gamma_{ii} = \gamma_{jj} = 1,\ \gamma_{ij} = \gamma_{ji} = 0$ or $\delta_{ii} = \delta_{jj} = 1,\ \delta_{ij} = \delta_{ji} = 0$ and the common values information structure has $\gamma_{ii} = \gamma_{ij} = \delta_{ji} = \delta_{jj} = 1$ or $\delta_{ii} = \delta_{ij} = \delta_{ji} = \delta_{jj} = 1$. The proof of Corollary 1 follows from the conditions in Theorem 1 after substituting the restrictions just mentioned.

Corollary 1: (Private and Common Values Information Structures):

(a) *For the common values information structure, the unique equilibrium has the managers of both firms adopting a policy of not disclosing their private information about customers with or without delegation. If the managers have private information about production costs, again the unique equilibrium has both managers adopting a policy of not disclosing their private information unless the incentive weights chosen by the owners of the two firms are sufficiently different. If so, then the owners placing greater emphasis on revenues induce their manager to adopt a policy of disclosure while their rival owners do not.*

(b) *For the private values information structure, the unique equilibrium has both managers adopting a policy of disclosing their private information about customers or production costs with or without delegation.*

Before turning to the owners' choices of optimal incentives, we can apply Theorem 2 in Bagnoli and Watts [2011] to extend the above analysis to the case when the firms are uncertain as to whether their information is, in fact, private. Bagnoli and Watts show that, as long as there is a positive probability that the information is private, the disclosure choices are the same as they would be

[15] For example, if incentives were based not on revenues but instead on output ($\lambda_i q_i^2$) then delegation would also impact the disclosure of private information about customers.

[16] Similar results on adopting a disclosure policy obtain if the managers are provided incentives to reduce costs or if the firms are Bertrand competitors in their product markets (details are available from the authors). We believe that this similarity may be related to the result in Miller and Pazgal [2001] who show that, in the presence of delegation with incentives that depend on the profits earned by both firms, Bertrand and Cournot competition are equivalent.

if the firms were certain that their information is private. Since the incentives associated with delegation do not affect the proof of their result, each firm's equilibrium delegation choice will not be affected by any uncertainty regarding whether or not the manager's information is private.

5. Stage 1: Delegation Decisions.

Working from the results in Proposition 1 and Theorem 1, we now turn to the owners' delegation decisions—how much emphasis to place on revenues in the manager's employment contract. Each owner chooses the incentive weight to maximize his expected profits taking into account both whether the manager will subsequently find it optimal to adopt a policy of disclosure and the impact on how she competes in the firm's product market. We assume that the owners choose the incentive weights simultaneously and that these choices are known by both managers.[17]

Recall that, from Proposition 1, each firm's expected profits are $\mathrm{E}[q_i^2(d_i, d_j)]$ and that the equilibrium choices of d_i and d_j are described in Theorem 1. We also make the following simplifying assumptions. First, when manager i has private information about customers, we simplify the structure of the firm's costs by assuming that $\delta_{ii} = 1$ and $\delta_{ij} = 0$. Second, when manager i has private information about costs, we simplify the structure of the firm's demand by assuming that $\gamma_{ii} = 1$ and $\gamma_{ij} = 0$. And, with a slight abuse of notation, we use D and N to represent the sets of parameters for which the firm's manager chooses to disclose her private information given the equilibrium incentive weights and equilibrium disclosure choices from Theorem 1.

Theorem 2: (a) *When the manager has private information about customers, the owners' equilibrium incentive weight is:*

$$\lambda_i(d_i, d_j) = -1 + \frac{\delta_{ii}\mathrm{E}[c_i]}{\gamma_{ii}\mathrm{E}[a_i] + \gamma_{ij}\mathrm{E}[a_j]} \qquad \forall d_i, d_j \in \{D, N\}.$$

(b) *When the manager has private information about costs, owners' equilibrium incentive weight is implicitly given by (for $i = 1, 2;\ j \neq i$):*[18]

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[17] We remind the reader that Kockesen [2007] shows that benefits similar to the type arising with observable contracts arise in settings such as ours when the act of delegation is observable even when the contract itself is not observable. In our setting, it is natural to assume that the act of delegation is observable and so we simplify the analysis by directly assuming that the contracts themselves are observable.

[18] The expressions for the equilibrium weights are messy and since the disclosure policy choice only depends on $\frac{1+\lambda_j}{1+\lambda_i}$, we find it more convenient to report this ratio, $R_i(d_i, d_j)$.

$$R_i(D,D) = \frac{B_i\mathrm{E}[mc_j]+D_i\mathrm{Var}[c_j]+F_j\mathrm{Var}[c_i]}{B_j\mathrm{E}[mc_i]+F_i\mathrm{Var}[c_j]+D_j\mathrm{Var}[c_i]} \qquad R_i(D,N) = \frac{B_i\mathrm{E}[mc_j]+A_i\mathrm{Var}[c_j]+F_j\mathrm{Var}[c_i]}{B_j\mathrm{E}[mc_i]-D_j\mathrm{Var}[c_i]}$$

$$R_i(N,D) = \frac{B_i\mathrm{E}[mc_j]+D_i\mathrm{Var}[c_j]}{B_j\mathrm{E}[mc_i]+F_i\mathrm{Var}[c_j]-A_j\mathrm{Var}[c_i]} \qquad R_i(N,N) = \frac{B_i\mathrm{E}[mc_j]+A_i\mathrm{Var}[c_j]}{B_j\mathrm{E}[mc_i]-A_j\mathrm{Var}[c_i]}$$

where:

$$\begin{aligned}
B_i &= \gamma_{ii}\mathrm{E}[a_i]\mathrm{E}[mc_i]\mathrm{E}[mc_j] \\
A_i &= {\delta_{jj}}^2(4-t^2)^2\mathrm{E}[mc_i](t\gamma_{jj}\mathrm{E}[a_j] - 2\gamma_{ii}\mathrm{E}[a_i]) \\
D_i &= \delta_{ii}\Big(2t\gamma_{ii}\mathrm{E}[a_i]\mathrm{E}[c_j](\delta_{ii}\delta_{jj} - \delta_{ij}\delta_{ji}) \\
&\qquad + \gamma_{jj}\mathrm{E}[a_j]\big((-4+t^2)\delta_{ii}\delta_{ji}\mathrm{E}[c_i] + (t^2\delta_{ij}\delta_{ji} - 4\delta_{ii}\delta_{jj})\mathrm{E}[c_j]\big)\Big) \\
F_i &= \delta_{ji}\Big(2t\gamma_{jj}\mathrm{E}[a_j]\mathrm{E}[c_j](\delta_{ij}\delta_{ji} - \delta_{ii}\delta_{jj}) \\
&\qquad + \gamma_{ii}\mathrm{E}[a_i]\big((-4+t^2)\delta_{ii}\delta_{ji}\mathrm{E}[c_i] + (t^2\delta_{ii}\delta_{jj} - 4\delta_{ij}\delta_{ji})\mathrm{E}[c_j]\big)\Big).
\end{aligned}$$

Theorem 2 indicates that all four disclosure adoption choices (neither firm disclosing, one firm disclosing, the other firm disclosing, or both disclosing) are possible in equilibrium but that delegation affects which obtain. If we initially focus on the managers having private information about costs, the starkest difference arises in the common values case. In this case, absent delegation, each firm chooses not to adopt a policy of disclosing its private information (Gal–Or 1985, 1986, Darrough 1993 and Theorem 1 when $\lambda_1 = \lambda_2 = 1$). Theorem 2 shows that this may not be the case when disclosure and operating decisions are delegated to the firm's manager. More specifically, in the common values case, if firm i's market is larger (smaller) than its rival's, then the manager of firm i (the manager of firm j) adopts a policy of disclosure when her cost uncertainty is large relative to her rival's. Thus, delegation can enhance the probability of at least one firm adopting a policy of disclosing its private information about costs.

Further, except in extremely unusual circumstances, delegation alters both the likelihood of adopting a policy of disclosure and what will be disclosed.[19] In particular, for the firm that puts greater incentive weight on revenues, delegation increases the likelihood of disclosure and biases disclosure away from information that is predominantly about the disclosing firm and toward information that is predominantly useful to the rival. For the other firm, delegation reduces the

[19] Formally, $R_i = 1$ for a set of $(\delta_{ii}, \delta_{ij}, \delta_{jj}, \delta_{ji})$'s with measure zero.

likelihood of disclosure but if the manager adopts a policy of disclosure, it biases the information the manager will disclose toward information about the manager's own firm. Thus, delegation shifts the information available to the market so that the market expects to learn more about the firm that places lower incentive weight on the firm's revenues and less about the firm that places greater incentive weight on the firm's revenues.

Our analysis also allows us to study how the equilibrium incentive weights are affected when both operating and disclosure choices are delegated to the manager. While the exact conditions depend on subsequent disclosure choices, there are three common conditions that lead the owners of one of the firms to place greater incentive weight on revenues than its rival owners. First, the firm with greater cost uncertainty places greater incentive weight on revenues (*i.e.*, firm i has greater cost uncertainty if $\text{Var}[c_i] > \text{Var}[c_j]$). Intuitively, the firm with greater cost uncertainty expects to earn greater expected profits and thus benefits more from shifting sales through the use of incentive weights. Second, the firm whose product market is expected to be larger places greater weight on revenues.[20] Intuitively, the reason is that if the firm's market is larger, the benefits to shifting sales are greater. Third and related, the firm that has the greater expected profit potential places greater incentive weight on revenues.[21] Intuitively, again, the firm with the greater expected profit potential benefits more from shifting sales through the use of incentive weights.

Finally, when the managers have private information about customers, Theorem 1 shows that delegation does not affect the disclosure policy choice and Theorem 2 shows that the owner that places greater incentive weight on revenues is the owner of the firm with the greater expected profit potential. This is the same as the last condition describing when the owner places greater incentive weight on revenues when the manager will have private information about the firm's costs.

6. The Impact of Delegation on Disclosure.

In this section, we combine our results from the prior two sections to analyze how delegation affects equilibrium disclosure. We focus our discussion on the manager's disclosure of her private information about costs because delegation does not impact the disclosure of private information about customers in our model. We should emphasize at the outset that none of these implications follow without delegation. That is, absent delegation, firm disclosure choices are not affected by

[20] Formally, firm i has a larger product market if $\gamma_{ii}\text{E}[a_i] > \gamma_{jj}\text{E}[a_j]$.

[21] Firm i has greater expected profit potential if $\gamma_{ii}\text{E}[a_i]/\text{E}[mc_i] > \gamma_{jj}\text{E}[a_j]/\text{E}[mc_j]$.

their expected profit margins, market sizes or *ex ante* cost uncertainty.

Theorem 2 indicates that the owners of the firm with the greater expected profit potential choose a larger incentive weight on revenues than its rival owners. Further, Theorem 1 indicates that the owners of the firm who choose the larger incentive weight have a manager who is more likely to disclose but who is less likely to disclose information that is predominantly about her own firm's costs. Since, in our model, the firm with the greater expected profit potential is the firm with the larger expected profit margin, our analysis implies that the disclosure choices of publicly traded firms depend on their expected profit margins. More specifically, firms with larger expected profit margins are more likely to provide disclosures and less likely to provide disclosures that are predominantly related to their own costs. Firms with smaller expected profit margins are less likely to provide disclosures but more likely to provide disclosures that are predominantly related to their own costs. As a result, our model predicts that the market will be provided more information about the cost structure of firms with smaller expected profit margins and less information about the cost structures of firms with larger expected profit margins.

This prediction is broadly consistent with the results in Verrecchia and Weber [2006] on redacted disclosures. They interpret redaction decisions as reduced voluntary disclosure and find that competitive industries (as measured using the industry's Herfindahl Index) redact less than less competitive industries. While there is significant debate as to whether the Herfindahl Index adequately captures the degree of competition (see Karuna [2007] and the references therein), if the index is correlated with profit margins, Verrecchia and Weber's results may be consistent with our empirical prediction. A more direct test could focus on voluntary disclosures of costs and how they are related to the firms' profit margins.

Dedman and Lennox [2009] focus on redactions by private companies in the U.K.[22] Their measure of competition is taken from a survey of the managers of these firms and measures the managers' perception of the competitive environment their firm faces. Dedman and Lennox find that managers who perceive competition to be greater more often choose to redact revenue and cost of sales information from their public filing. But, because their results focus only on private firms rather than the whole industry, it is difficult to know whether their results are related to the

[22] Private companies are required to provide financial statements to their shareholders and banks. They are also required to provide them to a central depository but are permitted to redact revenue and cost of sales from this filing.

larger or smaller firm in our analysis.

Li [2010] examines the relation between the percent of firms in an industry providing management forecasts of earnings (alternatively management forecasts of capital expenditures) and factor analysis based measures of industry competition. She finds that the fraction of firms in an industry providing disclosures is smaller in more competitive industries (but greater for industries where entry is a greater threat) and less pronounced for industry leaders. She interprets this last finding as likely the result of industry leaders facing less competition than industry followers.[23] While it is difficult to relate the factors Li uses to proxy for competition among rivals and entrants to the measures of competition in our model, our model may be useful in interpreting her last result on industry leaders and followers.

Lastly, Karuna [2011] focuses on voluntary disclosures of research and development costs, the number of employees and order backlog and relates disclosure choices to price–cost margin and market size. He finds that more competitive industries exhibit greater disclosure of both R& D costs and the number of employees. Since both are related to a firm's variable costs and thus most closely related to our analysis of disclosure of private cost information his results may be more closely related to our empirical predictions.

Theorem 2 also indicates that the firm serving the larger product market chooses a larger incentive weight on revenues than its rival does. Again, combining this with the results in Theorem 1 indicates that the manager of the firm with the larger product market is more likely to provide disclosures and less likely to provide disclosures that are predominantly related to her own firm's costs. Thus, our analysis predicts that managers of firms with greater market shares are more likely to provide disclosures but less likely to provide disclosures that are predominantly related to their own costs. Further, this suggests that the market will be provided more information about the cost structure of firms with small market shares and less information about the cost structures of firms with large market shares. As mentioned above, Karuna [2011] provides some evidence supporting this prediction.

Finally, Theorem 2 provides the first results concerning the firms' level of uncertainty and its effect on disclosure choice. Firms with greater *ex ante* cost uncertainty place greater incentive

[23] One would need to extend our analysis to allow for fixed costs in order to relate our model to the voluntary disclosure of capital expenditures.

weight on revenues which results in managers of those firms being more likely to provide a disclosure but less likely to provide a disclosure that is predominantly about their own costs. The managers of firms with less *ex ante* cost uncertainty are less likely to provide a disclosure but more likely to provide a disclosure that is predominantly related to their own costs. Thus, our model predicts that the market will be provided more information about the cost structure of firms with smaller cost uncertainty and less information about firms with greater cost uncertainty. This suggests that less information will be provided for firms with shorter production histories or in industries where input costs are particularly variable.

Our analysis also offers insights into how the aforementioned empirical implications vary depending on whether the firms sell more or less differentiated products. Recall that a larger value of t means that the firms' products are more homogeneous. Given this, Theorem 1 implies that the effect of differences in incentive weights are exacerbated for firms selling more homogeneous products. As a result, our analysis suggests that firms that adopt cost leadership strategies will see larger effects from differences in profitability, market shares and *ex ante* uncertainty about production costs. On the other hand, firms that adopt product differentiation strategies will see smaller effects from differences in profitability, market shares and *ex ante* uncertainty about production costs. These predictions may also be consistent with the results reported by Verrecchia and Weber [2006] mentioned above if increased product differentiation is associated with less competitive Herfindahl Indices. Further, if Karuna's [2011] conjecture that profit margins are associated with product differentiation, this result is consistent with his finding that disclosure is inversely related to the degree of product heterogeneity and may provide some insight into the non–linear relation that he uncovers.

7. Conclusions.

Our objective in this paper is to examine the joint delegation of operating and disclosure decisions in a multiprincipal–agent setting. Since separation of ownership and control is essentially the defining characteristic of the modern corporation, we develop a model to study the effects when owners of a firm delegate both the firm's operating and disclosure decisions to a manager. We show that joint delegation alters the owner's willingness to bias the manager's operating choice toward greater sales and biases the manager's disclosure away from disclosing information about the firm's own costs. In particular, when compared to the disclosure policy adoption decision in the absence of delegation, with delegation, the owners who put greater incentive weight on the

firm's revenues bias their manager's disclosure adoption decision away from disclosing information predominantly about the firm's own costs and toward disclosing information that helps the rival better understand its costs. The bias is reversed when the owners place smaller incentive weight on their firm's revenues. The net effect is, however, that the owners placing greater incentive weight on revenues increase the likelihood of disclosure by their manager and the owners placing smaller incentive weight on revenues decrease the likelihood of disclosure by their manager. Delegation of operating and disclosure choices has no effect if the manager has private information about customers rather than costs.[24] We also find that the incentive weights differ based on the owners' anticipation of the managers' disclosure policy choices.

Our analysis also allows us to determine the conditions under which the owners of one firm place greater incentive weight on revenues than the owners of the rival firm do: owners of the firm with greater expected market share, greater expected profit potential or greater *ex ante* cost uncertainty put greater incentive weight on revenues. Intuitively, these are the conditions that produce greater benefits from trying to shift sales toward the firm and away from its rival. Combining these results with our results on the effects of differing incentive weights on disclosure allows us to conclude that the market will be provided with more (less) information about the cost structure of firms with smaller (larger) expected profit margins, smaller (larger) expected market shares or less (more) cost uncertainty. Our results on the effect of *ex ante* cost uncertainty also suggest that firms with shorter histories and firms in industries where the prices of important inputs are particularly variable are less likely to provide voluntary disclosures. These empirical predictions have not been tested directly but are consistent with some of the empirical results in the literature that examine the relation between industry competitiveness and disclosures (see, for example Verrecchia and Weber [2006], Li [2010] and Karuna [2011]). We hope that our analysis, which focuses on disclosure of variable costs and particular measures of competitiveness, will assist empirical researchers as they work to improve our understanding of the effects of competitiveness on disclosure.

[24] This result appears to be due to the linearity of demand and the contract offered to the manager.

8. Appendix

Proof of Proposition 1: Firm i solves $\max_{q_i}\ \mathrm{E}[(1+\lambda_i)(\gamma_{ii}a_i+\gamma_{ij}a_j-q_i-tq_j)q_i-(\delta_{ii}c_i+\delta_{ij}c_j)q_i \mid \phi_i]$ which yields the first order condition $q_i = \mathrm{E}\big[\frac{1}{2}(\gamma_{ii}a_i + \gamma_{ij}a_j - tq_j) - \frac{1}{2(1+\lambda_i)}(\delta_{ii}c_i + \delta_{ij}c_j) \mid \phi_i\big]$. Each of the cases differ in that the firms' information sets are different. For example, if both have committed to disclose, then both know a_i, a_j, c_i and c_j. In other words, the firms play a game of complete information and we obtain the standard result for $q_i(D,D)$. If firm i has committed to disclose but firm j has not, then firm i does not learn a_j and/or c_j. As a result, firm i's first order condition becomes $q_i = \mathrm{E}\big[\frac{1}{2}(\gamma_{ii}a_i + \gamma_{ij}\mathrm{E}[a_j] - t\mathrm{E}[q_j]) - \frac{1}{2(1+\lambda_i)}(\delta_{ii}c_i + \delta_{ij}\mathrm{E}[c_j]) \mid \phi_i\big]$ and firm j's remains the same. Solving produces $q_i(D,N)$ and, by symmetry $q_i(N,D)$. The final case, when both firms commit not to disclose, the first order conditions are again $q_i = \mathrm{E}\big[\frac{1}{2}(\gamma_{ii}a_i + \gamma_{ij}\mathrm{E}[a_j] - t\mathrm{E}[q_j]) - \frac{1}{2(1+\lambda_i)}(\delta_{ii}c_i + \delta_{ij}\mathrm{E}[c_j]) \mid \phi_i\big]$. Solving this pair of equations yields $q_i(N,N)$. In each case, substituting the equilibrium quantities into the firm's objective function produces the expression for profits given in the Proposition. ∎

Proof of Theorem 1: Our proof strategy is to show that $\mathrm{E}[\pi_i^C(D,N)] > \mathrm{E}[\pi_i^C(N,N)]$ and then that $\mathrm{E}[\pi_i^C(D,D)] > \mathrm{E}[\pi_i^C(N,D)]$ which are the conditions required for disclosure to be the dominant strategy. Similarly, reversing the inequalities yields the conditions required for non–disclosure to be the dominant strategy. Direct computations show that[25]

$$\begin{aligned}
&\mathrm{E}[\pi_i^C(D,N)]-\mathrm{E}[\pi_i^C(N,N)] = \mathrm{E}[\pi_i^C(D,D)] - \mathrm{E}[\pi_i^C(N,D)] \\
&\quad= \left(\frac{-t}{4(1+\lambda_i)(1+\lambda_j)^2(4-t^2)^2}\right) \\
&\qquad\qquad \Big[(1+\lambda_i)^2(1+\lambda_j)^2(-2\gamma_{ji}+t\gamma_{ii})(-8\gamma_{ii}+2t\gamma_{ji}+t^2\gamma_{ii})\mathrm{Var}[a_i] \\
&\qquad\qquad + (-4t(1+\lambda_i)^2{\delta_{ji}}^2 + 16(1+\lambda_i)(1+\lambda_j)\delta_{ij}\delta_{ji} + t(1+\lambda_j)^2(-8+t){\delta_{ii}}^2)\mathrm{Var}[c_i]\Big].
\end{aligned}$$

Thus, if (C1) holds, disclosure of private information about customers is firm 1's dominant strategy. If (C1) fails, non–disclosure is firm 1's dominant strategy. Similarly, if (C2) holds, disclosure of private information about production costs is firm 1's dominant strategy. If (C2) fails, non–disclosure is firm 1's dominant strategy. ∎

Proof of Theorem 2: Each firm chooses the incentive weight to offer its manager simultaneously and so we determine their equilibrium choices in the usual way. First, firm i solves $\max_{\lambda_i(d,d)} \mathrm{E}[q_i(d,d)^2]$ which yields the first order condition $0 = \mathrm{E}[2q_i(d,d)\frac{\partial q_i(d,d)}{\partial \lambda_i}]$. When the manager has private information about customers, the firms' reaction functions are:

$$\lambda_i = -1 + \frac{(2(1+\lambda_j)\mathrm{E}[mc_i]}{\big((1+\lambda_j)(2\gamma_{ij}-t\gamma_{jj})\mathrm{E}[a_j] + (1+\lambda_j)(2\gamma_{ii}-t\gamma_{ji}) + t\mathrm{E}[mc_j]\big)}.$$

Solving this pair of equations yields the equilibrium λ's as reported in the Theorem.

[25] In the following expression, only one of the variances is non–zero, the one associated with the firm's private information. We write the expression with both variances for convenience and to illustrate the similarities in the conditions that lead to the firm choosing to disclose its private information about customers or about costs.

The incentive weights when the manager has private information about costs are computed in the same way. The firms' reaction functions are quite tedious as are the equilibrium λ's. As a result, we report the equilibrium ratios $(1+\lambda_j)/(1+\lambda_i)$. ∎

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