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Executive Compensation, Strategic Competition, and Relative Performance Evaluation: Theory and Evidence

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ABSTRACT

We examine compensation contracts for managers in imperfectly competitive product markets. We show that strategic interactions among firms can explain the lack of relative performance-based incentives in which compensation decreases with rival firm performance. The need to soften product market competition generates an optimal compensation contract that places a positive weight on both own and rival performance. Firms in more competitive industries place greater weight on rival firm performance relative to own firm performance. We find empirical evidence of a positive sensitivity of compensation to rival firm performance that is increasing in the degree of competition in the industry.

THE SEPARATION OF OWNERSHIP AND CONTROL in corporations is a central feature of modern economies. The largely unobserved choice of actions by a firm's managers can have a major impact on the wealth of its shareholders. The literature on principal-agent theory suggests that the primary means for shareholders to ensure that a manager takes optimal actions is to tie her pay to the performance of her firm. If the manager is risk averse, this use of high-powered incentives will be tempered by the extent to which the performance of the firm is affected by random shocks. However, if the shocks to firm performance are correlated across firms in an industry, then the optimal incentive scheme compensates a firm's manager on the performance of her firm relative to those of the other firms (see Holmström (1982)). The principal-agent and relative performance evaluation models provide a compelling theoretical framework for understanding executive compensation.

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The empirical literature on the relative performance evaluation model is inconclusive. Jensen and Murphy (1990) find that relative performance evaluation is not an important source of managerial incentives. Gibbons and Murphy (1990) and Antle and Smith (1986) test more directly for relative performance pay and find that, holding constant the rate of return on a firm's common stock, a higher value-weighted industry rate of return lowers the growth of CEO pay. In contrast, Barro and Barro (1990), Joh (1999), and Janakiraman, Lambert, and Larcker (1992), using a variety of data sources, all find that compensation increases with industry performance. Aggarwal and Samwick (1999) explicitly test cross-sectional predictions of a relative performance evaluation model and find no evidence of relative performance evaluation. The lack of strong empirical results suggests that other factors beyond the effort-insurance trade-off are important in the design of compensation contracts.[1]

The typical principal-agent model fails to recognize that the interaction between shareholders and managers occurs in an environment of strategic interactions between firms in imperfectly competitive markets. Relative performance evaluation filters out a common industry shock by placing a positive weight on the own firm's performance and a negative weight on the industry's performance. This negative industry pay-performance sensitivity implies that an executive will receive higher compensation if executives of other firms in the industry deliver lower returns to their shareholders. Although the relative performance evaluation contract reduces the executive's exposure to risk, it provides incentives to take actions that lower industry returns. If rival firms in an industry are strategic competitors, then a compensation contract that filters out a common shock necessarily alters a manager's optimal strategic product market choices.

Our analysis tests for the effects of strategic competition on relative performance evaluation in executive compensation contracts. We first derive the optimal compensation contracts for managers allowing for strategic interactions in the product market. We demonstrate that the use of relative performance evaluation may be limited by the need to soften product market competition. Our model yields the sharp empirical prediction that there will be less relative performance evaluation in more competitive industries. Using recent, comprehensive data on executive compensation, we find robust empirical support for this prediction. Our results suggest that strategic interactions between firms are an important reason why the predictions of the standard principal-agent model of relative performance evaluation are not supported empirically.

[1] There is also a literature that examines the magnitude of the pay-performance sensitivity. Jensen and Murphy (1990) find that the compensation of chief executive officers increases by only \$3.25 per \$1,000 increase in shareholder wealth. Haubrich (1994) shows that some parameterizations of the principal-agent model allow for pay performance sensitivities as low as the 0.003 found by Jensen and Murphy. See also later work by Hall and Liebman (1998) and Aggarwal and Samwick (1999).

Our work is related to three literatures in corporate finance and the theory of the firm. The first shows that other types of financial contracts, such as debt contracts, can have important implications for the nature of product market competition. A number of models show how capital structure choices can change the intensity of strategic competition (Bolton and Scharfstein (1990), Rotemberg and Scharfstein (1990), Maksimovic (1988), and Brander and Lewis (1986)). In these models, firms choose capital structure prior to engaging in product market competition. Debt serves to commit managers to either intensify or soften strategic competition, depending on model parameters. Empirical tests of these models are found in Chevalier (1995a, 1995b), Phillips (1995), and Kovenock and Phillips (1997). Our paper provides analogous theoretical and empirical evidence on the relationship between compensation contracts and product market competition.

The second literature links the severity of the principal-agent problem to the degree of competition in product markets. Hart (1983), Scharfstein (1988), Hermalin (1992), and Schmidt (1997) consider whether product market competition induces managers to improve efficiency by increasing their supply of effort. These papers show how increasing the number of competitors in a product market changes the provision of effort by managers. However, they do not allow compensation contracts to influence competition in the product market as we do.

The third literature shows that precommitment to managerial incentive contracts can alter strategic competition between rival firms, as in Vickers (1985), Fershtman and Judd (1987), and Sklivas (1987).[2] Fumas (1992) extends this literature to include relative performance evaluation contracts in a model similar to ours. Because Fumas's model is more general than ours, it does not generate readily testable implications.

We model product market competition in two ways—as strategic complements and strategic substitutes. When outputs are strategic complements, as in the differentiated Bertrand model of price competition, relative performance pay lowers the shareholders' returns by encouraging more aggressive price setting by managers and is therefore not observed in equilibrium. In this case, the level of compensation under the optimal contract increases with both own-firm and rival-firm performance, softening competition and raising the returns to shareholders. Furthermore, the model generates the strong prediction that the optimal compensation contract is sensitive to the degree of competition in the firm's product market. In more competitive industries, managers are given weaker incentives to maximize the value of their own firms and stronger incentives to maximize the value of all firms in the industry. The strategic complements model predicts that the ratio of the own-firm pay-performance sensitivity to the rival-

[2] See also Katz (1991) and Reitman (1993). Joh (1999) and Kedia (1996) provide empirical tests of strategic interactions in compensation data. Kedia (1996) tests the Fershtman and Judd (1987) model by defining strategic complements and substitutes following the methodology of Sundaram, John, and John (1996).

firm pay-performance sensitivity is a decreasing function of the level of competition in the industry. These contracts increase the value of the manager's own firm relative to contracts that do not explicitly take into account the strategic interaction.

When firm outputs are strategic substitutes, as in a differentiated Cournot model, the level of compensation in the optimal contract increases with own-firm performance but decreases with rival-firm performance. Such a contract resembles relative performance pay, but the contract is motivated by the nature of the strategic interaction and not a principal-agent problem. This model also predicts that the optimal compensation contract will be sensitive to the degree of competition in the firm's product market. In more competitive industries, managers are given weaker incentives to maximize the value of their own firm and stronger incentives to minimize the value of other firms in the industry. The model predicts that the ratio of the own-firm pay-performance sensitivity to the rival-firm pay-performance sensitivity is a decreasing function of the level of competition in the industry. The intuition for these contracts is that they commit the manager to behaving aggressively in the product market in order to deter competitors.

We test these predictions by linking together two sources of data. We use industry concentration ratios from the Census of Manufactures to characterize product market competition and compensation data for executives of large corporations from the Standard and Poor's ExecuComp dataset. There are three main empirical results. First, we find that both own- and rival-firm pay-performance sensitivities are positive for total compensation. Second, the ratio of the own- to rival-firm pay-performance sensitivity is lower in more competitive industries. These two results support the strategic complements model and are inconsistent with the strategic substitutes model and a relative performance evaluation model. Third, we find some evidence of relative performance evaluation in short-term compensation data, but even here the extent of relative performance evaluation is limited by strategic competition. More competitive industries have less negative rival-firm pay-performance sensitivities. These results show that strategic interactions between firms in an oligopoly may explain the puzzling lack of relative performance evaluation in executive compensation contracts.

The paper is organized as follows. In Section I, we derive the form of optimal executive compensation contracts under differentiated Bertrand competition when contracts can vary with own and industry performance. Two important extensions of this model are contained in the appendices. In Appendix A, the differentiated Bertrand model is embedded in a fully specified principal-agent framework. We show that the comparative static predictions of Section I are robust to the inclusion of an effort-insurance trade-off. In Appendix B, we relax the assumption that contracts are publicly observable and instead assume that they are unobservable. We present a signaling model in which the equilibrium contracts have the same qualitative properties as the contracts derived in Section I. Section II repeats the analysis of Section I under the assumption that competition is differentiated Cournot. In Section III, we describe the data that we use for our empirical tests. In Section IV, we present our econometric results and discuss their implications for alternative theories of executive compensation. Section V concludes.

I. Bertrand Competition

We consider the following contracting model. There are two firms, 1 and 2, in an industry which engage in differentiated Bertrand competition. The model has two stages. At stage 1, the owners of the firms write contracts with the managers, and at stage 2 the managers engage in differentiated Bertrand competition (our derivation will apply to any model with strategic complements). We assume a manager's action choice at stage 2 is noncontractible.[3] Profits, or statistics for profits such as returns to shareholders, are contractible. Firms face symmetric demand functions given by

$$D_i(p_i,p_j) = A - bp_i + ap_j, \tag{1}$$

where $i,j \in \{1,2\}$, $i \neq j$. We assume that $b > a$. That is, the manager's action choice has a greater impact on the demand for her own product than does her rival's action. We assume linear demands and two firms because this specification yields straightforward comparative statics across product markets. The results of our model generalize to nonlinear demand functions so long as $\partial D_i/\partial p_i < 0$, $\partial D_i/\partial p_j > 0$, and $|\partial D_i/\partial p_i| > \partial D_i/\partial p_j$. It is important to note for our empirical tests that our results on optimal contracts also generalize straightforwardly to industries with more than two firms.

Profits are given by

$$\pi_i = (p_i - c)(A - bp_i + ap_j) + \varepsilon. \tag{2}$$

ε is a mean zero common shock to profits with variance σ^2. Therefore, prices (or, more generally, the manager's noncontractible strategic action choice) cannot be perfectly inferred from profits. Marginal cost is assumed constant and is given by c. In this section, we do not consider managerial risk aversion or effort choices. We introduce these in Appendix A, and show that the results derived in this section continue to hold in a fully specified principal-agent model.

[3] In our model, it does not matter if we make the standard moral hazard assumption that the manager's strategic action choice is unobservable or if we make the incomplete contracts assumption that the manager's strategic action choice is observable but not verifiable. The latter may be more realistic in our setting, but all we require is that the action choice be noncontractible for either reason.

At stage 1, if contracts are written contingent solely on own-firm profits, we get the standard differentiated Bertrand result. Any contract that is increasing in own profits will induce the manager to choose the profit-maximizing price. Equilibrium prices and expected profits are

$$p_i^* = \frac{A + bc}{2b - a} \tag{3}$$

and

$$E[\pi_i^*] = b\,\frac{(A - bc + ac)^2}{(2b - a)^2}. \tag{4}$$

Can the standard contract be improved upon? Would the owners of the firms raise their profits by offering their managers contracts contingent on rival-firm profits as well as own-firm profits? Suppose the following linear contract is offered to the manager of firm i:[4]

$$w_i = k_i + \alpha_i \pi_i + \beta_i \pi_j. \tag{5}$$

In this model, the owner of firm i chooses the contract, the contract is revealed to both managers, and then the managers choose prices.[5] We put no restrictions on α_i and β_i; they could be greater than one or less than zero. We assume that the manager of firm i has a reservation wage w_i' and that the managerial labor market is competitive. Therefore, the k_is, which are constants unrelated to performance, are chosen so that the managers are always held to their reservation wages. The first-period program for the owner of firm i is

$$\begin{aligned} &\max_{\alpha_i, \beta_i, k_i} E[\pi_i] - w_i \\ &\text{s.t.} \quad w_i \geq w_i' \quad \text{and} \\ &p_i^{**} \in \arg\max_{p_i} w_i. \end{aligned} \tag{6}$$

[4] Linear contracts impose some restriction on the contracting space. We focus on linear contracts for three reasons. First, linear contracts are analytically tractable. The assumption of linearity is standard in the literature on precommitment through incentive contracts (e.g., Fershtman and Judd (1987), Fumas (1992)). Second, linear compensation contracts are consistent with the Holmström and Milgrom (1987) principal-agent framework, which we further develop in Appendix A. Third, as in the previous empirical literature on compensation, the linear specification generates comparative statics that can be directly tested.

[5] The public revelation and observability of contracts are not essential to the model. In Appendix B, we derive conditions under which unobservable contracts can still achieve the results of this section.

The first constraint is the manager's individual rationality constraint, which will always bind through the choice of k_i. The second constraint ensures that the manager's second-period action choice is optimal given the first-period contract.

We start by analyzing the second-period action choice of each firm's manager in the differentiated Bertrand game. The manager of firm i solves

$$\max_{p_i} \alpha_i((p_i - c)(A - bp_i + ap_j) + \varepsilon) + \beta_i((p_j - c)(A - bp_j + ap_i) + \varepsilon). \tag{7}$$

Firm i's reaction function is

$$R_i'(p_j) = \frac{A + bc + ap_j}{2b} + \frac{\beta_i a(p_j - c)}{2\alpha_i b}. \tag{8}$$

The optimal price level as a function of contracts for firm i is

$$p_i^{**} = \frac{-\alpha_j A(\alpha_i a + 2b\alpha_i + \beta_i a) - \alpha_j bc(2b\alpha_i + \alpha_i a - \beta_i a) + a^2 c\beta_j(\alpha_i + \beta_i)}{-4\alpha_i b^2\alpha_j + \alpha_i a^2\alpha_j + \alpha_i a^2\beta_j + \beta_i a^2\alpha_j + \beta_i a^2\beta_j}. \tag{9}$$

Substituting the price choices back into the owners' first-period problems and holding the managers to their reservation wages yields the following program for firm i:

$$\max_{\alpha_i, \beta_i} E[(p_i^{**} - c)(A - bp_i^{**} + ap_j^{**}) + \varepsilon] - w_1^i. \tag{10}$$

Jointly solving both firms' programs gives a continuum of optimal contracts for each firm's manager, which is

$$\begin{aligned} \alpha_1^{**} &= \frac{2b - a}{a} y, \qquad \beta_1^{**} = y, \qquad y \in \Re^+. \\ \alpha_2^{**} &= \frac{2b - a}{a} z, \qquad \beta_2^{**} = z, \qquad z \in \Re^+. \end{aligned} \tag{11}$$

We can now solve for the symmetric equilibrium prices, p_i^{**}:

$$p_i^{**} = \frac{A(2b - a) + c(b - a)(2b + a)}{4b(b - a)}, \tag{12}$$

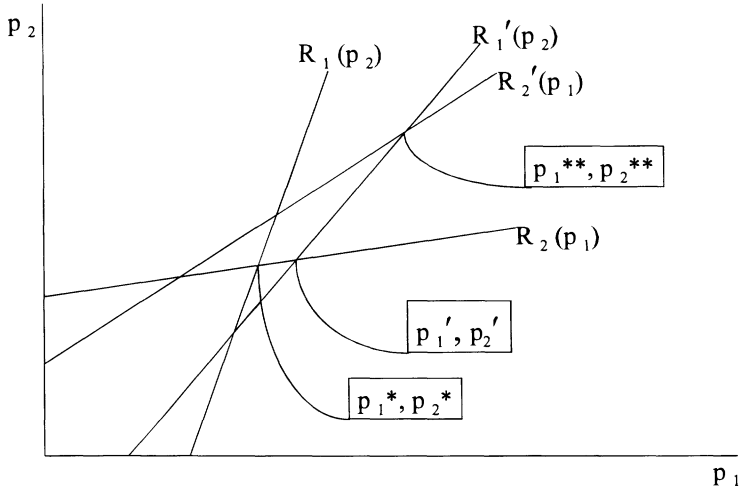

Figure 1. Bertrand reaction functions. $R_1(p_2)$ and $R_2(p_1)$ are reaction functions under standard differentiated Bertrand competition. Equilibrium prices are (p_1^*, p_2^*). $R_1'(p_2)$ and $R_2'(p_1)$ are the reaction functions when managers can be compensated on both own- and rival-firm profits. At (p_1', p_2') the owner of firm 1 uses a contract based on own- and rival-firm profits and the owner of firm 2 uses a contract based on own-firm profits. When both firms use contracts based on own- and rival-firm profits, the equilibrium prices are (p_1^{**}, p_2^{**}).

and expected profits:

$$E[\pi_i^{**}] = \frac{1}{16}(4b^2 - a^2)\frac{(A - bc + ac)^2}{(b - a)b^2}. \tag{13}$$

A direct comparison shows that expected prices and profits in the case where both managers can be compensated on own-firm and rival-firm profits are greater than expected prices and profits when both managers are compensated strictly on their own-firm profits, as long as the noncontractual differentiated Bertrand price is greater than marginal cost.

Figure 1 depicts the shift in equilibria as we move from standard differentiated Bertrand competition to competition with compensation contracts based on own- and rival-firm profits. The upward sloping lines labeled $R_1(p_2)$ and $R_2(p_1)$ are firm 1 and firm 2's reaction functions under standard differentiated Bertrand competition. The lines labeled $R_1'(p_2)$ and $R_2'(p_1)$ are the reaction functions when managers can be compensated on both own- and rival-firm profits. At (p_1', p_2'), the owner of firm 1 uses a contract based on own- and rival-firm profits and the owner of firm 2 uses a contract based on own-firm profits. Prices and profits are higher for both firms relative to standard differentiated Bertrand competition. When both firms use contracts based on own- and rival-firm profits, the new equilibrium prices (p_1^{**}, p_2^{**}) and profits are even higher.

Allowing a manager to be compensated on rival-firm profits lessens competition and raises profits for both firms. Recall from equation (11) that the optimal contracts $(\alpha_i^{**}, \beta_i^{**})$ are functions of a and b. The relative weight put on own-firm profits in the optimal contract is an increasing function of b, the effect of own price, and a decreasing function of a, the effect of the rival firm's price. The ratio b/a measures the degree of substitutability between the two firms' products. A higher value of b/a indicates lower substitutability—that is, an industry that is closer to separate monopolies. A lower value of b/a indicates greater substitutability—that is, an industry that is more competitive in the sense that price is closer to marginal cost.

The optimal contracts are only identified up to their ratio, α^{**}/β^{**}, and not to their levels. This is a result of the continuum of equilibria. We call this ratio the *compensation ratio*. The differentiated Bertrand model makes the following comparative static prediction:

$$\frac{\partial\left(\dfrac{\alpha^{**}}{\beta^{**}}\right)}{\partial\left(\dfrac{b}{a}\right)} > 0. \tag{14}$$

The compensation ratio is increasing in the degree of product differentiation. In other words, as the products become more substitutable, more weight is put on rival-firm profits relative to own-firm profits to offset the increased competitive pressure. We test this prediction in Section IV, as well as the predictions of equation (11) that $\alpha^{**} > 0$ and $\beta^{**} > 0$.

To make the intuition for this result clearer, consider two industries. In the first, products of rival firms are close substitutes. For a given reduction in the price of its product, a firm in this industry can appropriate a larger share of the market from its rival. Since in equilibrium, the rival firm will respond in kind, it is precisely this industry in which managers need to be given strong incentives to maintain a higher price. In our model, shareholders provide these incentives by placing a relatively larger weight on rival-firm performance. In the second industry, products are more differentiated, so that each firm has a local monopoly. Managers in this industry are less inclined to reduce price to steal market share because a given reduction in price results in lower profits from inframarginal customers. Shareholders therefore do not need to provide strong incentives to support prices through the compensation contract. Hence, the relative weight on rival-firm performance is lower.

The predictions we generate come from a model in which we have fully specified the nature of the firms' product market interaction without fully specifying the nature of the principal-agent relationship within the firms. In our setup, it is clear that optimal compensation contracts depend on product market characteristics. A more complete model would also include risk aversion on the part of the manager and both an effort choice and a disutility of effort for the manager. Optimal contracts would depend on these factors as well in order to produce a fully integrated principal-agent model of product market competition. In Appendix A, we present such a model using the linear principal-agent framework of Holmström and Milgrom (1987). The predictions of equations (11) and (14) are unaffected.

Our model can also be understood as identifying a cost of relative performance evaluation contracts. In our model, optimal contracts put a positive weight on both own- and rival-firm performance. Relative performance evaluation contracts put a negative weight on the rival firm to filter out common shocks. However, putting a negative weight on the rival firm induces managers to compete more aggressively in the product market, which hurts firm profitability. The use of relative performance evaluation will be limited by the need to curtail managers' incentives to compete aggressively in the product market.

In our model, the manager's compensation contract is publicly observable in order to serve as a commitment device. This assumption is not essential to derive our basic comparative statics. In Appendix B, we derive similar results while dispensing with the observability of contracts. The key to this result is that managers can take actions to signal their unobservable contracts to the product market. Credibly signaled contracts restore the commitment value of contracts but do not require direct observability of the contracts by the market or other outsiders. Because profits are higher when rival-firm performance is rewarded in the contract, the firm's owner can afford to fund the costly signal by the manager. The manager sends the signal because softening competition raises her compensation through both the own- and rival-firm pay-performance sensitivities.

The contracts we derive clearly facilitate collusive behavior. Compensating a manager positively on the performance of her industry may seem to violate antitrust laws. However, Gilo (1996) documents numerous cases of firms that hold passive equity positions in rival firms and shows that such passive investments are permitted under Section 7 of the Clayton Antitrust Act. Gilo argues that such passive investments may have anticompetitive effects, and in this section we demonstrate one mechanism by which collusion might be sustained. Nonetheless, having a positive rival-firm pay-performance sensitivity does not violate antitrust laws. Additionally, there are no legal constraints on firms limiting the amount of relative performance evaluation they employ in order to curb aggressive price setting by managers. We predict that firms in more competitive industries use less relative performance evaluation than do firms in less competitive industries.

II. Cournot Competition

Now we consider the same model as in Section I but characterize the market with differentiated Cournot competition instead of Bertrand competition. Prices as functions of quantities are

$$P_i(q_i, q_j) = A - bq_i - aq_j, \tag{15}$$

and profits are given by

$$\pi_i = q_i(A - bq_i - aq_j - c) + \varepsilon. \tag{16}$$

The standard differentiated Cournot solution obtains if the manager is compensated strictly on own-firm profits. Equilibrium quantities and expected profits are

$$q_i^* = \frac{A - c}{a + 2b} \tag{17}$$

and

$$E[\pi_i^*] = \frac{b}{(a + 2b)^2}(A - c)^2. \tag{18}$$

In order to compare the Cournot case to the Bertrand case, we again consider linear compensation contracts:

$$w_i = k_i + \alpha_i \pi_i + \beta_i \pi_j. \tag{19}$$

The first-period program for the owner of firm i is

$$\begin{gathered} \max_{\alpha_i, \beta_i, k_i} E[\pi_i] - w_i \\ \text{s.t.} \quad w_i \geq w_i' \quad \text{and} \\ q_i^{**} \in \arg\max_{q_i} w_i. \end{gathered} \tag{20}$$

The second-period action choice of firm i's manager is given by

$$\max_{q_i} \alpha_i(q_i(A - bq_i - aq_j - c) + \varepsilon) + \beta_i(q_j(A - aq_i - bq_j - c) + \varepsilon). \tag{21}$$

The reaction function for firm i is

$$R_i'(q_j) = \frac{A - c}{2b} - \frac{aq_j(\alpha_i + \beta_i)}{2\alpha_i b}. \tag{22}$$

The optimal quantity choice for firm i as a function of contracts is

$$q_i^{**} = \alpha_j(A - c)\frac{\alpha_i a - 2\alpha_i b + \beta_i a}{-4\alpha_j b^2 \alpha_i + \alpha_i a^2 \beta_j + \alpha_i a^2 \alpha_j + \beta_i a^2 \beta_j + \beta_i a^2 \alpha_j}. \tag{23}$$

Substituting the optimal quantity choices back into the owner's first-period problem and holding the manager to her reservation wage yields the following program:

$$\max_{\alpha_i,\beta_i} E[q_i^{**}(A - bq_i^{**} - aq_j^{**} - c) + \varepsilon] - w_i'. \tag{24}$$

Jointly solving both firms' programs gives a continuum of optimal contracts for each firm's manager:

$$\begin{aligned} \alpha_1^{**} &= \frac{2b+a}{a}y, \quad \beta_1^{**} = -y, \quad y \in \Re^+. \\ \alpha_2^{**} &= \frac{2b+a}{a}z, \quad \beta_2^{**} = -z, \quad z \in \Re^+. \end{aligned} \tag{25}$$

These contracts have the feature that each manager is given a long position in her own firm and a short position in her rival's firm. In principle there is an additional continuum of optimal contracts in which each manager is given a short position in her own firm and a long position in her rival. Although both types of contracts are theoretically possible, legal constraints prevent a manager from shorting her own firm. Section 16(c) of the Securities Exchange Act of 1934 prohibits insiders from maintaining short positions in their own firms' equity securities.[6] Hansen and Lott (1995) demonstrate that no such constraints exist on taking a short position in a rival firm. We thus refer to the contract in which the manager of a firm is given a long position in her own firm and a short position in her rival as the equilibrium contract.

Given the above contracts, the symmetric equilibrium quantities, q_i^{**}, are

$$q_i^{**} = \frac{1}{4b}(A - c)\frac{a+2b}{a+b}. \tag{26}$$

Expected profits are

$$E[\pi_i^{**}] = \frac{1}{16}(4b^2 - a^2)\frac{(A-c)^2}{(a+b)b^2}. \tag{27}$$

A direct comparison shows that expected quantities are higher and expected profits are lower in the case where both managers can be compensated on own- and rival-firm profits relative to the case where both managers are compensated strictly on their own-firm profits.

[6] According to SEC Document No. S7-26-88, "A reading of the legislative history indicates that Congress did not want insiders, with access to inside information, speculating in their company's stock by acquiring short positions. Further, Congress did not want insiders to take short positions in conflict with their fiduciary duties, because insiders could use short positions to manipulate a stock price or to profit by a fall in the price of their company's stock."

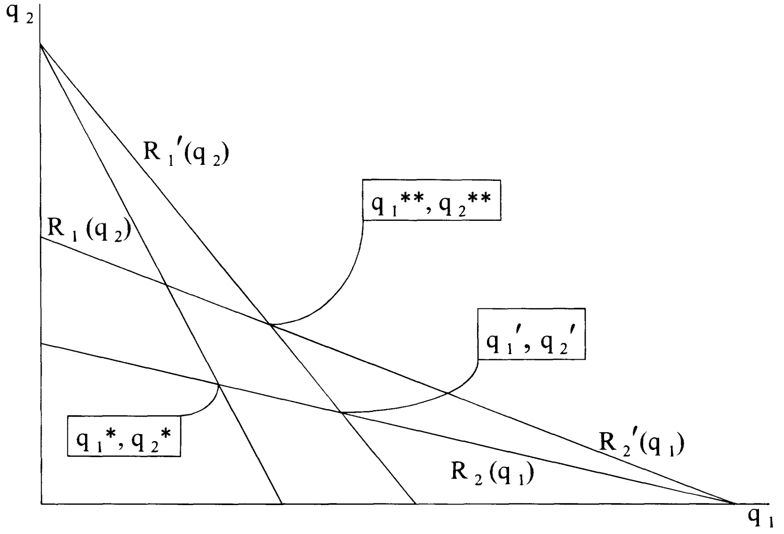

Figure 2. Cournot reaction functions. $R_1(q_2)$ and $R_2(q_1)$ are reaction functions under standard differentiated Cournot competition. Equilibrium quantities are (q_1^*, q_2^*). $R_1'(q_2)$ and $R_2'(q_1)$ are the reaction functions when managers can be compensated on both own- and rival-firm profits. At (q_1', q_2') the owner of firm 1 uses a contract based on own- and rival-firm profits and the owner of firm 2 uses a contract based on own-firm profits. When both firms use contracts based on own- and rival-firm profits, the equilibrium quantities are (q_1^{**}, q_2^{**}).

For the differentiated Cournot model, the compensation ratio is decreasing in the degree of product differentiation:

$$\frac{\partial\left(\dfrac{\alpha^{**}}{\beta^{**}}\right)}{\partial\left(\dfrac{b}{a}\right)} < 0. \tag{28}$$

As the industry becomes more competitive, relatively more negative weight is put on the rival and less positive weight is put on the own firm. This commits the manager to acting more aggressively in the product market.

Figure 2 depicts the shift in equilibrium as we move from standard differentiated Cournot competition to competition with compensation contracts based on own- and rival-firm profits. The downward sloping lines labeled $R_1(q_2)$ and $R_2(q_1)$ are firm 1 and firm 2's reaction functions under standard differentiated Cournot competition. The lines labeled $R_1'(q_2)$ and $R_2'(q_1)$ are the reaction functions when managers can be compensated on both own- and rival-firm profits. At (q_1', q_2'), the owner of firm 1 uses a contract based on own- and rival-firm profits and the owner of firm 2 uses a contract based on own-firm profits. Firm 1 produces a higher quantity and firm 2 produces a lower quantity, and firm 1's profits are higher than under standard differentiated Cournot competition. Therefore, if one firm does not use contracts based on own- and rival-firm performance, then the other firm is better off using a contract based on own- and rival-firm performance. When both firms use contracts based on own- and rival-firm profits, the new equilibrium quantities are (q_1^{**}, q_2^{**}), which are higher than the equilibrium quantities in standard differentiated Cournot competition, and profits are lower for both firms. The use of contracts based on own- and rival-firm performance creates the usual Prisoners' Dilemma among Cournot competitors.[7]

In our model, the optimal contracts exhibit short-selling of the rival by both of the firms—β_i^{**} is negative. Shorting one's rival resembles relative performance evaluation. The manager does get compensated on the difference between her firm's performance and the rival firm's performance. However, what looks like relative performance evaluation is not the result of the owner's need to provide the agent with incentives to supply effort while filtering out the common shock ε. Instead, the negative weight on rival-firm performance arises because the owner wants to toughen competition—it is a strategic choice rather than a response to moral hazard.

III. Data

The models of Sections I and II yield testable implications for the relationship between product substitutability and the sensitivity of executive compensation to firm performance. We combine compensation data from the Standard and Poor's Compustat ExecuComp database with product market data from the Commerce Department's Census of Manufactures to test our predictions. This section describes each of these data sources in turn.

The ExecuComp dataset compiled by Standard and Poor's includes data on total compensation for the top five executives (ranked annually by salary and bonus) at each of the firms in the S&P 500, S&P Midcap 400, and S&P SmallCap 600. In addition to measures of short-term compensation such as salary and bonus, ExecuComp contains data on components of long-term compensation such as long-term incentive plans, restricted stock, and stock appreciation rights. Due to enhanced federal reporting requirements for fiscal years ending after December 15, 1992, the ExecuComp data for 1993 through 1995 are virtually complete. Table I presents descriptive statistics on the components of executive compensation for all executives in the Ex-

[7] Our results of higher quantities and lower profits are similar to those of Fershtman and Judd (1987) and Sklivas (1987), who consider contracts in which the manager is compensated on a linear combination of own-firm profits and sales rather than of own- and rival-firm profits. Fumas (1992) also obtains results similar to ours. In another related model, Lemmon (1997) shows that when the relative sensitivity of the managers' compensation to current and future performance can be strategically adjusted by owners, managers can be induced to either over- or underinvest. Because investment competition is competition in strategic substitutes, over- or underinvestment results from Prisoner's Dilemma behavior between the rival managers.

Table I

Summary Statistics for Components of Executive Compensation in 1995

This table reports summary statistics for the components of executive compensation in the 1995 sample year. All calculations are based on the Standard and Poor's ExecuComp dataset and are reported in thousands of dollars. Statistics are reported separately based on whether the executive is identified as the Chief Executive Officer (CEO) of the firm. The group of CEOs consists of the executives at each company that held the CEO position for the majority of the year. The group of non-CEOs consists of the other four highest paid executives at each company ranked by salary plus bonus. Total compensation is equal to short-term compensation plus long-term compensation. Short-term compensation is the sum of salary, bonus, and other annual compensation. Long-term compensation is the sum of restricted stock granted, stock options granted, long-term incentive plan payouts, and all other compensation.

Payment Category (thousands of dollars)	Mean	Median	First Quartile	Third Quartile	Standard Deviation
CEOs (N = 1519)					
Total compensation	2205	1276	689	2474	3446
Short-term compensation	1060	770	484	1215	1882
Salary	535	475	333	668	299
Bonus	491	250	54	550	1794
Other annual	33	0	0	6	139
Long-term compensation	1146	438	77	1149	2497
Restricted stock granted	152	0	0	0	638
Stock options granted	793	244	0	762	2148
LT incentive plan payouts	116	0	0	0	529
All other	84	17	5	60	326
Long-term share of total	0.357	0.353	0.110	0.555	0.257
Non-CEOs (N = 6305)					
Total compensation	927	550	328	1026	1353
Short-term compensation	474	355	233	563	441
Salary	275	238	175	333	150
Bonus	183	100	30	220	336
Other annual	16	0	0	1	92
Long-term compensation	454	162	44	446	1089
Restricted stock granted	58	0	0	0	271
Stock options granted	298	92	0	277	891
LT incentive plan payouts	47	0	0	0	211
All other	51	9	4	27	377
Long-term share of total	0.330	0.316	0.133	0.494	0.233

ecuComp sample for 1995. The top panel of the table pertains to the 1,519 executives who are identified as the chief executive officers of the firms. The bottom panel describes the other 6,305 executives in the sample.[8]

[8] The sample in 1995 contains more than 1500 firms because a firm's executives are included in the sample in every year after that firm appears in the top 1500, even if the firm subsequently drops out of that group. Similarly, there are some firms in which more than five executives are included in the later years of the sample. See Standard and Poor's (1995) for details.

We divide total compensation into short-term and long-term components. Short-term compensation consists of salary, bonus, and other annual payments (e.g., gross-ups for tax liabilities, perquisites, preferential discounts on stock purchases). Short-term compensation averages \$1,060,000 for the CEOs and \$474,000 for the non-CEOs. Long-term compensation includes the value of restricted stock granted, stock options granted, payouts from long-term incentive plans, and all other compensation (e.g., contributions to benefit plans, severance payments). The sample averages of long-term compensation are \$1,146,000 for CEOs and \$454,000 for non-CEOs. In the aggregate, long-term compensation accounts for 52.0 percent of CEO compensation and 49.0 percent of non-CEO compensation. At the individual level, the average share of compensation that is long-term is 35.7 percent for CEOs and 33.0 percent for non-CEOs. The large difference between the aggregate and the individual long-term shares reflects the skewness in the distribution of long-term compensation across executives. Stock options granted are by far the most important component of long-term compensation, accounting for 69.2 percent for CEOs and 65.6 percent for non-CEOs.[9]

Our differentiated Bertrand and Cournot models link the compensation contract to the ratio b/a, where b is the slope of the demand curve with respect to the firm's action choice and a is the slope of the demand curve with respect to the rival's action choice. Firms in industries in which there is little product differentiation (i.e., high product substitutability) have a low ratio of b/a. In both models, compensation becomes more sensitive to own-firm performance relative to rival-firm performance as product differentiation, measured by the ratio b/a, increases.

Because there is no cross-sectional index of the degree of product substitutability, we use the industry Herfindahl Index as a proxy for product substitutability. For firms that produce for more than one industry, we assign the Herfindahl using the COMPUSTAT "Principal Products" Standard Industrial Classification (SIC) code for the firm's largest business segment. The use of the Herfindahl assumes there is a one-to-one correspondence between four-digit SIC codes and product markets, but this correspondence is not perfect. Even at the four-digit level, some industries may include several products that are not themselves close substitutes for each other. This aggregation tends to overstate the true substitutability for a firm's product. This mismeasurement due to aggregation is unlikely to be systematically different across industries and consequently unlikely to bias our empirical results.

Our source of data for the Herfindahl Index is the 1992 Census of Manufactures, conducted by the Bureau of the Census as part of the quinquennial Economic Censuses.[10] Table II, Panel A, presents descriptive statistics

[9] The value of stock options granted is estimated by a proprietary modified Black–Scholes formula. See Standard and Poor's (1995) for a discussion.

[10] The data and documentation of the concentration ratios are found in Bureau of the Census (1996). The Economic Censuses for other sectors of the economy do not include proxies for substitutability and so are excluded from our empirical analysis.

Table II

Summary Statistics and Examples for Concentration Ratios in the Census of Manufactures, 1992

This table provides the distributions of Herfindahl Indices across industries based on the Census of Manufactures, 1992. In this data, the Herfindahl Index is defined at the four-digit SIC level as the sum of squared market shares for the largest 50 firms in that industry. Market shares are expressed as percentages (0 to 100), so that Herfindahls can vary from 0 to 10,000. Standard Industrial Classifications (SICs) are hierarchical, with each successive digit from the left distinguishing related industries more finely. All of the four-digit SICs that begin with the same two digits are related. For each of the 20 two-digit SIC codes in the manufacturing sector, Panel A reports the number of four-digit SICs represented in the ExecuComp sample, along with the average, minimum, and maximum Herfindahls of those four-digit SICs. Panel B sorts the four-digit SICs represented in the ExecuComp sample by their Herfindahls and gives an example of three sample firms in each of the top (most concentrated), middle, and bottom (least concentrated) quintiles of the Herfindahl distribution.

Panel A: Four-Digit SIC Concentration Ratios by Two-Digit SIC Code

2-Digit SIC Code and Description	Number of 4-digit SICs	Herfindahls of Constituent 4-digit SICs: Average	Minimum	Maximum
20: Food and kindred products	22	1076.1	181	2253
21: Tobacco products	2	2090.6	1923	2175
22: Textile mill products	8	740.7	243	1679
23: Apparel and other textile products	8	805.3	61	2338
24: Lumber and wood products	5	283.6	78	491
25: Furniture and fixtures	5	521.7	167	1043
26: Paper and allied products	5	453.9	143	1451
27: Printing and publishing	8	404.2	19	2922
28: Chemicals and allied products	22	640.4	190	2999
29: Petroleum and coal products	2	414.8	414	431
30: Rubber and miscellaneous plastic products	7	386.2	15	1743
31: Leather and leather products	3	786.0	513	1401
32: Stone clay and glass products	5	891.3	472	1765
33: Primary metal industries	11	859.0	201	2827
34: Fabricated metal products	16	348.7	31	1457
35: Industrial machinery and equipment	24	660.5	80	2549
36: Electronic and other electric equipment	26	745.5	180	2929
37: Transportation equipment	11	1538.7	428	2717
38: Instruments and related products	15	467.3	148	2408
39: Miscellaneous manufacturing industries	6	265.8	74	808
All Manufacturing Industries	211	699.1	15	2999

Panel B: Herfindahl Indices of Representative Four-Digit SICs, by Quintile

4-Digit SIC Code and Description	Herfindahl	Sample Firm
Top quintile		
3711: Motor vehicles and car bodies	2676	General Motors
2111: Cigarettes	2175	RJR Nabisco
2082: Malt beverages	2041	Anheuser-Busch
Middle quintile		
3312: Blast furnaces and steel mills	551	Nucor
3674: Semiconductors and related devices	541	Intel
3541: Metal cutting machine tools	403	Kennametal
Bottom quintile		
2731: Book publishing	251	McGraw-Hill
2891: Adhesives and sealants	245	Loctite
2421: Sawmills and planing mills, general	78	Louisiana-Pacific

on the variation of Herfindahl Indices by two-digit SICs. Within the manufacturing sector are the 20 two-digit SIC codes from 20 to 39. The 622 manufacturing firms in our ExecuComp sample are drawn from 211 of the 458 separate four-digit SICs (ranging from 2001 to 3999) in the Census of Manufactures.[11] The table shows that there is wide variation in average concentration within and across broad industry groups.

This variation corresponds to differences in product substitutability across industries. Firms in more concentrated industries have fewer close substitutes for their products and therefore higher values of b/a. Salop (1979) shows that in equilibrium the optimal location for firms in the product space maximizes the distance between competitors. In this model, industries with more firms have greater product substitutability and lower concentration ratios. Extending this logic to product markets with firms of different sizes, industries in which a small number of firms have disproportionately large market shares will exhibit greater product differentiation. The Herfindahl Index captures the impact of both the number of firms and their relative market shares on the degree of product substitutability in an industry.[12]

The logic that industry concentration corresponds to product substitutability is consistent with our data. Table II, Panel B, presents the Herfindahl Indices for representative four-digit SICs in the top, middle, and bottom quintiles of the Herfindahl distribution. Those firms in the most concentrated quintile in our sample (motor vehicles, cigarettes, beer) have very strong brand identification and are therefore highly differentiated. Those firms in the middle quintile have products that exhibit some brand identification (blast furnaces and steel mills, semiconductors, metal cutting machine tools) but that are also somewhat substitutable. Those firms in the least concentrated quintile (sawmills, adhesives and sealants, book publishing) produce commodity products that are highly substitutable across different suppliers.

IV. Empirical Results

Recall that our theoretical model specifies executive compensation as a linear combination of own- and rival-firm profits:

$$w_i = k_i + \alpha_i \pi_i + \beta_i \pi_j, \tag{29}$$

where α and β also represent the own- and rival-firm pay-performance sensitivities. In the differentiated Bertrand model, both α and β are positive. In the differentiated Cournot model, α is positive and β is negative. In both

[11] The Census of Manufactures calculates an industry's Herfindahl Index as the sum of the squared shares of the industry's total value of shipments for the largest 50 firms. In the few SICs in which the Herfindahl Index is missing, we construct the value from the 4-, 8-, 20-, and 50-firm concentration ratios.

[12] Bresnahan and Salop (1986) also use a modified Herfindahl Index as a measure of the degree of competition in imperfectly competitive markets.

models, the weight on own-firm profits relative to rival-firm profits—the compensation ratio (α/β)—is a decreasing (in absolute value) function of the degree of substitutability between the two firms' products. In other words, as products become more substitutable (markets become more competitive), an executive's pay will depend less on own-firm performance and more on the performance of rival firms.

In order to estimate pay-performance sensitivities, we specify both parameters of the compensation contract as linear functions of the percentile of the firm's industry in the distribution of concentration ratios:

$$\begin{aligned} \frac{\partial w_i}{\partial \pi_i} &= \alpha_i = \eta_1 + \eta_3 F(H), \\ \frac{\partial w_i}{\partial \pi_j} &= \beta_i = \eta_2 + \eta_4 F(H), \end{aligned} \tag{30}$$

where $F(H)$ is the sample cumulative distribution function (c.d.f.) of the Herfindahl across four-digit SICs. In our sample, the Herfindahl for the least concentrated industry is 15, so $F(15) = 0$. The median Herfindahl is 491 ($F(491) = 0.50$) and the maximum Herfindahl is 2999 ($F(2999) = 1$) . We use the c.d.f. of H as a convenient normalization that allows for easy interpretation of the parameters, η_k, in a regression framework.

Given the equations in equation (30), both of the theoretical models make predictions about the slope of the compensation ratio as a function of the Herfindahl:

$$R(\boldsymbol{\eta}) \equiv \frac{\partial\left(\dfrac{\alpha}{\beta}\right)}{\partial F(H)} = \frac{\eta_2\eta_3 - \eta_1\eta_4}{\left(\eta_2 + \eta_4 F(H)\right)^2}. \tag{31}$$

The differentiated Bertrand model predicts that $R(\eta) > 0$, and the differentiated Cournot model predicts that $R(\eta) < 0$. When specified as either of these inequalities, equation (31) is a single nonlinear restriction on the parameters of a linear regression that we fully specify below in equations (37) through (39). The test statistic is therefore distributed asymptotically as

$$W = R(\boldsymbol{\eta})'\left(G(\boldsymbol{\eta})\hat{V}(\boldsymbol{\eta})G(\boldsymbol{\eta})'\right)^{-1}R(\boldsymbol{\eta}) \sim \chi^2(1), \tag{32}$$

where

$$G(\boldsymbol{\eta}) \equiv \frac{\partial R(\boldsymbol{\eta})}{\partial \boldsymbol{\eta}'}, \tag{33}$$

and $\hat{V}(\boldsymbol{\eta})$ is the estimated variance-covariance matrix of the parameters. Each term in the test-statistic depends on the value of $F(H)$. In our empirical work, we test the null hypothesis at the median industry concentration ratio, $F(H) = 0.50$.

In our theoretical models, we refer to π_j as the "profits" to firm j. More precisely, π_j is the present discounted value of all future cash flows that will accrue to the firm as a result of the executive's current strategic action. Following Jensen and Murphy (1990), we use the market's estimate of these cash flows: the total real dollar returns to shareholders on their holdings at the beginning of the period. Own performance for firm j is defined as

$$\pi_{jt}^{o} = \rho_{jt} W_{j,t-1}, \tag{34}$$

where ρ_{jt} is the total inflation-adjusted return to shareholders and $W_{j,t-1}$ is the beginning of period market value of firm j. In our dataset consisting of large firms in 1993–1995, the mean and median values for $W_{j,t-1}$ are \$3.2 billion and \$796 million (in constant 1995 dollars), respectively.

We define the total inflation-adjusted return to shareholders of rival firms as

$$\rho_{-j,t} = \frac{\sum_{k \neq j} \rho_{kt} W_{k,t-1}}{\sum_{k \neq j} W_{k,t-1}}, \tag{35}$$

where the summations are taken over all firms excluding firm j in the same SIC code. In our dataset, the 25th, 50th, and 75th percentiles of ρ_{jt} and $\rho_{-j,t}$ are $\{-11.15\%, 7.89\%, 30.35\%\}$ and $\{-2.74\%, 10.46\%, 25.25\%\}$, respectively. Our measure of rival-firm performance is

$$\pi_{jt}^{r} = \rho_{-j,t} W_{j,t-1}. \tag{36}$$

Rival-firm performance is the hypothetical dollar returns to shareholders of firm j if it experienced the value-weighted average return of other firms in its industry.

Studies of relative performance evaluation typically include $\pi_{jt}^{o} - \pi_{jt}^{r}$ as an explanatory variable in a regression for compensation. We extend that framework by including π_{jt}^{o} and π_{jt}^{r} separately and by interacting them with the industry concentration ratio. Accordingly, we estimate the following equation:

$$\begin{aligned} w_{ijt} = {} & \eta_0 + \eta_1 \pi_{jt}^{o} + \eta_2 \pi_{jt}^{r} + \eta_3 F(H_j) \pi_{jt}^{o} + \eta_4 F(H_j) \pi_{jt}^{r} \\ & + \eta_5 F(H_j) + \eta_6 CEO_{it} + \sum_{k=21}^{39} \mu_{jk} + \sum_{t=94}^{95} \psi_t + \varepsilon_{ijt}. \end{aligned} \tag{37}$$

In this equation, executive i works at firm j in year t. The dependent variable is compensation. The first four independent variables are own- and rival-firm performance, alone and interacted with the c.d.f. of the Herfindahl. The regressions also include $F(H_j)$ and a dummy variable for whether the executive is a CEO. The terms denoted by μ_{jk} are indicator variables for whether firm j is in the two-digit SIC k. The terms denoted by ψ_t are dummy variables for time periods.

When estimating the parameters of our theoretical model, we must allow for the possibility that other factors that affect both firm performance and compensation are left unspecified in the model. Equation (37) proxies for such factors by including the Herfindahl and the dummy variables for year, two-digit SIC, and CEO. Our estimates of η_1 through η_4 will be unbiased if these proxies absorb all the correlation between performance and the level of compensation due to these unspecified factors. In order to make our argument robust to the possibility that they do not, we also consider two variants of equation (37). The first specifies the dependent variable as the annual change in compensation for each executive rather than including industry dummies:

$$\begin{aligned}\Delta w_{ijt} &= \eta_0 + \eta_1 \pi^o_{jt} + \eta_2 \pi^r_{jt} + \eta_3 F(H_j)\pi^o_{jt} + \eta_4 F(H_j)\pi^r_{jt} \\ &\quad + \eta_5 F(H_j) + \eta_6 CEO_{it} + \sum_{t=94}^{95} \psi_t + \varepsilon_{ijt}.\end{aligned} \tag{38}$$

Equation (38) purges the estimates of any correlation between performance and the level of compensation that is not also correlated with the change in compensation. The second specifies both the dependent and independent variables in annual changes:

$$\begin{aligned}\Delta w_{ijt} &= \eta_1 \Delta\pi^o_{jt} + \eta_2 \Delta\pi^r_{jt} + \eta_3 F(H_j)\Delta\pi^o_{jt} + \eta_4 F(H_j)\Delta\pi^r_{jt} \\ &\quad + \eta_6 \Delta CEO_{it} + \sum_{t=94}^{95} \psi_t + \Delta\varepsilon_{ijt}.\end{aligned} \tag{39}$$

Equation (39) corresponds to equation (37) estimated with an executive fixed effect. The inclusion of fixed effects controls for all factors about the executive, such as ability, and the firm, such as average sales or other measures of firm size, that do not change over time. In moving from equation (37) to equation (38) to equation (39), we guard against possible omitted variable bias by using progressively less of the variation in the compensation and performance data to estimate the coefficients. There is a cost to moving from equation (37) to equation (39). Our theory specifically predicts a relationship between the level of compensation and the dollar returns to shareholders (equation (37)). Because only the correlation in the changes of compensation and performance (and not the levels) is used to estimate the coefficients in equation (39), our ability to reject the null hypotheses is weakened.

We present our main results in Table III. We estimate median regressions because the skewness of the distribution of executive compensation (especially long-term compensation) documented in Table I suggests that there are many outliers in the data. Median regressions minimize the sum of ab-

Table III
Median Regressions of Pay-Performance Sensitivity

This table estimates median regressions of the pay-performance sensitivity based on the ExecuComp and Census of Manufactures datasets. The dependent variables are total compensation in Panel A and short-term compensation in Panel B. Each panel consists of three sets of regressions, corresponding to equations (37) through (39):

$$w_{ijt} = \eta_0 + \eta_1 \pi^o_{jt} + \eta_2 \pi^r_{jt} + \eta_3 F(H_j)\pi^o_{jt} + \eta_4 F(H_j)\pi^r_{jt} + \eta_5 F(H_j) + \eta_6 CEO_{it} + \sum_{k=21}^{39} \mu_{jk} + \sum_{t=94}^{95} \psi_t + \varepsilon_{ijt} \quad (37)$$

$$\Delta w_{ijt} = \eta_0 + \eta_1 \pi^o_{jt} + \eta_2 \pi^r_{jt} + \eta_3 F(H_j)\pi^o_{jt} + \eta_4 F(H_j)\pi^r_{jt} + \eta_5 F(H_j) + \eta_6 CEO_{it} + \sum_{t=94}^{95} \psi_t + \varepsilon_{ijt} \quad (38)$$

$$\Delta w_{ijt} = \eta_1 \Delta\pi^o_{jt} + \eta_2 \Delta\pi^r_{jt} + \eta_3 F(H_j)\Delta\pi^o_{jt} + \eta_4 F(H_j)\Delta\pi^r_{jt} + \eta_6 \Delta CEO_{it} + \sum_{t=94}^{95} \psi_t + \Delta\varepsilon_{ijt} \quad (39)$$

Each set of regressions is estimated once with product market rivals defined at the four-digit level and once with rivals defined at the three-digit level. All dollar values are in thousands (compensation) or millions (performance) of constant 1995 dollars. Coefficients for years and two-digit SICs (in equation (37)) are not reported. Standard errors are in parentheses under each coefficient. For the hypothesis tests, p-values are reported in brackets beneath each estimate.

	Dependent Variable in Levels (37)		Dependent Variable in Differences (38)		All Variables in Differences (39)	
Regression Coefficients	4-digit	3-digit	4-digit	3-digit	4-digit	3-digit
Panel A: Dependent Variable Is Total Compensation						
Own performance (η_1)	0.0174	0.0365	0.0052	0.0037	0.0090	0.0046
	(0.0093)	(0.0109)	(0.0054)	(0.0049)	(0.0033)	(0.0032)
Rival performance (η_2)	0.1771	0.1853	0.0417	0.0357	0.0343	0.0348
	(0.0099)	(0.0123)	(0.0062)	(0.0060)	(0.0030)	(0.0030)
Own performance × Herf. percentile (η_3)	0.1654	0.1235	0.0451	0.0485	−0.0046	0.0106
	(0.0137)	(0.0143)	(0.0076)	(0.0064)	(0.0047)	(0.0043)
Rival performance × Herf. percentile (η_4)	−0.1501	−0.1076	−0.0557	−0.0388	−0.0529	−0.0554
	(0.0136)	(0.0168)	(0.0082)	(0.0080)	(0.0040)	(0.0043)
Herfindahl percentile	171.5108	188.4870	35.4712	27.3194	—	—
	(23.9572)	(26.2003)	(10.3482)	(8.9811)		

CEO indicator	717.2828	719.6419	37.4817	39.3022	−9.1162	106.1011
	(13.0437)	(15.3694)	(6.9180)	(6.1632)	(28.3453)	(25.3731)
Pseudo R^2	0.1306	0.1362	0.0153	0.0157	0.0038	0.0037
Number of observations	7793	8873	6198	7042	6044	6899
Hypothesis tests at the median industry concentration ratio ($F(H) = 0.5$)						
Own performance	0.1001	0.0983	0.0277	0.0280	0.0067	0.0099
[p-value]	[0.0000]	[0.0000]	[0.0000]	[0.0000]	[0.0000]	[0.0000]
Rival performance	0.1020	0.1315	0.0139	0.0163	0.0078	0.0071
[p-value]	[0.0000]	[0.0000]	[0.0000]	[0.0000]	[0.0000]	[0.0000]
Compensation ratio test	3.0643	1.5507	11.2634	7.0409	5.2022	12.2990
[p-value]	[0.0000]	[0.0000]	[0.0024]	[0.0000]	[0.0640]	[0.0226]
Panel B: Dependent Variable Is Short-Term Compensation						
Own performance (η_1)	0.0372	0.0493	0.0153	0.0190	0.0115	0.0112
	(0.0058)	(0.0057)	(0.0014)	(0.0014)	(0.0012)	(0.0012)
Rival performance (η_2)	0.0441	0.0510	−0.0031	−0.0054	−0.0010	−0.0011
	(0.0062)	(0.0065)	(0.0015)	(0.0016)	(0.0011)	(0.0011)
Own performance × Herf. percentile (η_3)	0.0389	0.0120	0.0069	0.0017	−0.0096	−0.0072
	(0.0086)	(0.0075)	(0.0021)	(0.0019)	(0.0017)	(0.0016)
Rival performance × Herf. percentile (η_4)	−0.0175	−0.0090	−0.0039	−0.0012	−0.0034	−0.0025
	(0.0085)	(0.0088)	(0.0020)	(0.0022)	(0.0015)	(0.0016)
Herfindahl percentile	56.9516	84.6361	4.2570	6.9131	—	—
	(15.0494)	(13.3780)	(3.0955)	(2.3260)		
CEO indicator	394.0433	398.6802	28.7684	29.7873	126.4191	121.6832
	(8.1857)	(7.8430)	(2.0907)	(2.0642)	(11.3166)	(10.3505)
Pseudo R^2	0.1600	0.1609	0.0261	0.0274	0.0075	0.0078
Number of observations	7794	8874	7182	8178	6972	7985
Hypothesis tests at the median industry concentration ratio ($F(H) = 0.5$)						
Own performance	0.0567	0.0553	0.0188	0.0198	0.0067	0.0076
[p-value]	[0.0000]	[0.0000]	[0.0000]	[0.0000]	[0.0000]	[0.0000]
Rival Performance	0.0354	0.0464	−0.0050	−0.0060	−0.0026	−0.0024
[p-value]	[0.0000]	[0.0000]	[0.0000]	[0.0000]	[0.0000]	[0.0000]
Compensation Ratio Test	1.8917	0.4895	1.5375	0.3867	6.8884	6.3750
[p-value]	[0.0003]	[0.1458]	[0.0024]	[0.7031]	[0.0111]	[0.0531]

solute deviations rather than the sum of squared deviations and are therefore less sensitive to outliers than are the ordinary least squares regressions presented in Table IV below. Table III, Panel A, presents the estimates from median regressions of equations (37) through (39) with total compensation as the dependent variable.

The first column pertains to a regression in which the firm's rivals are all other firms in the sample with the same four-digit SIC code. We use the four-digit SIC to define the rival firm because it is the finest level of disaggregation available in our data. The own-firm pay-performance sensitivity is determined by $\eta_1 + \eta_3 F(H)$. It ranges from 1.74 to 18.28 cents of compensation for every thousand dollars of incremental shareholder wealth per year in moving from the least concentrated ($F(H) = 0$) to the most concentrated ($F(H) = 1$) industries.[13] The bottom panel of the table shows that the pay-performance sensitivity is $1.74 + 0.50 * 16.54 = 10.01$ cents at the median.[14] The pay-performance sensitivities implied by the estimates in the third column with the change in compensation as the dependent variable are 0.52, 2.77, and 5.03 cents at the minimum, median, and maximum industry concentration ratios, respectively. Jensen and Murphy (1990) find that for the change in total compensation, the pay-performance sensitivity is 3.29 cents per thousand, which is close to our estimate of 2.77 cents at the median industry concentration. The fifth column reports the estimates using the specification in equation (39) in which both compensation and performance are specified in differences. The qualitative results are the same as in the other two specifications. The estimated pay-performance sensitivities at the median are somewhat smaller, although still statistically significant.

Each regression also estimates the rival-firm pay-performance sensitivities. The second and fourth coefficients in the first column show that the rival pay-performance sensitivity is 17.71 cents in the least concentrated industry, declining to 10.20 and 2.70 cents at the median and maximum concentration ratios, respectively. The rival pay-performance sensitivities implied by the estimates in the third column with the change in compensation as the dependent variable are 4.17, 1.39, and -1.40 cents at the minimum, median, and maximum industry concentration ratios, respectively. In all cases, the rival-firm pay-performance sensitivities are statistically significant and positive at the median.[15]

[13] In all specifications, executive compensation is denominated in thousands and firm performance is denominated in millions of constant 1995 dollars. A coefficient of 0.01 indicates one cent of compensation per thousand dollars of shareholder wealth. All pay-performance sensitivities are discussed in the text as cents per thousand.

[14] The variance-covariance matrix of the parameters and goodness-of-fit statistic are estimated using the method of Koenker and Bassett (1982) and Rogers (1993), as described in StataCorp (1995).

[15] The other coefficients in the first column show that total compensation increases by approximately \$17,200 for every decile increase in the distribution of the Herfindahl and increases by approximately \$717,000 if the executive is the CEO.

A drawback to using four-digit SICs to define the rivals is that there are a number of four-digit SICs in which ExecuComp has only one sample firm. To address this problem, we estimate another regression in which the performance of a firm's rivals is measured by the value-weighted returns to all other sample firms in the firm's three-digit SIC. In this specification, we are using three-digit SIC industry returns to approximate four-digit SIC industry returns for all of the firms in our sample. We continue to measure product differentiation as the value of $F(H)$ for the firm's four-digit SIC. The sample size increases in this specification by approximately 900 observations (about 300 executives in each of the three years). The second, fourth, and sixth columns of Table III, Panel A, present our estimates of this specification. The results are qualitatively the same and as statistically significant as the results of the specifications using four-digit SIC returns.[16]

There are several aspects of the regression results that are useful in identifying which model—Bertrand, Cournot, or relative performance evaluation—is generating the data. All predict that the own-firm pay-performance sensitivity is positive, but only the Bertrand model predicts that the rival-firm pay-performance sensitivity is positive. Since this is found at the median for each specification in Table III, Panel A, the Bertrand model is supported by the data and the others are rejected. The Bertrand model also makes the prediction that the compensation ratio, α/β, is increasing in $F(H)$. The last row of Panel A presents the test of the nonlinear restriction on the parameters specified as equation (31). The restriction takes on a value of 3.0643 and has a p-value equal to 0.0000 in the levels regression, 11.2634 with a p-value of 0.0024 in the differences regression, and 5.2022 with a p-value of 0.0640 in the last specification. The p-values are somewhat lower when the rivals are defined at the three-digit SIC. The positive and significant values of the restriction further indicate that the differentiated Bertrand model is supported by the data.[17]

Other authors such as Gibbons and Murphy (1990) and Antle and Smith (1986) find that the rival-firm pay-performance sensitivity is negative, which is consistent with a relative performance evaluation model but not the Bertrand model as derived in Section I. The difference between our results and theirs is essentially that we estimate $\eta_2 > 0$, so that we find $\beta = \eta_2 + \eta_4 F(H) > 0$.[18] It is certainly possible that the data are being generated by a model that combines elements of both the Bertrand and relative performance evaluation models. In any such model, strategic competition and relative performance evaluation would work against each other. To the extent that relative performance evaluation is present, it should be found dis-

[16] Using the performance of sample firms in the same two-digit SIC adds only a few additional observations and does not substantially alter the estimated coefficients.

[17] We have also tested the null hypothesis of $R(\eta) = 0$ at other values of $F(H)$. The p-values tend to be slightly lower (higher) at industry concentration ratios below (above) the median.

[18] In Appendix A, we show in the context of the Holmström and Milgrom (1987) linear principal-agent model augmented to include differentiated Bertrand competition that optimal contracts never have $\beta \leq 0$. The empirical result that $\beta > 0$ thus has fairly robust theoretical support.

proportionately in less competitive (i.e., more concentrated) industries. The prediction that strategic competition limits relative performance evaluation can be tested by simply observing whether $\eta_4 < 0$, a result that obtains and is significant in every regression in Table III, Panel A.

Table III, Panel B, presents the estimates of the same six regressions using short-term compensation as the dependent variable. When the dependent variable is the change in compensation, the main difference in the results is that $\eta_2 < 0$, leading to a negative rival pay-performance sensitivity. This is consistent with a relative performance evaluation model. However, it is still the case that $\eta_4 < 0$, so that the extent of relative performance evaluation is limited by strategic competition. There is less relative performance evaluation in industries with lower concentration (i.e., more competition), as suggested by our Bertrand model.[19] The compensation ratio test is insignificant. In the specifications with both compensation and performance in differences, we also obtain evidence consistent with relative performance evaluation limited by strategic competition. The compensation ratio test rejects the null in favor of the differentiated Bertrand model.

As discussed above, we utilize median regressions in Table III to mitigate the impact of outliers on our estimates. Table IV, Panels A and B, present the same regressions as in Table III, Panels A and B, estimated using ordinary least squares. For total compensation, the estimates from the regressions with the level of compensation as the dependent variable are qualitatively similar to those in Table III, which support the Bertrand model. The estimates in Table IV, Panel B, with the change in short-term compensation as the dependent variable, are also similar to those in Table III, Panel B, which show evidence of relative performance evaluation and of strategic interactions limiting the amount of relative performance evaluation across industries. The main difference is in the estimates in Table IV, Panel A, in which the dependent variable is the change in total compensation. In these regressions, the rival pay-performance sensitivities are negative and largely insignificant, and no support is provided for the Bertrand model. The results for the specifications with both compensation and performance in differences are mixed.

As another way to investigate the sensitivity of the OLS results to outliers, we run the regressions excluding observations at the top and bottom of the distribution of compensation. If the top and bottom 2.5 percent of the sample are omitted, then the OLS results closely resemble the median regression results in Table III, Panel A, that support the Bertrand model. We also run robust regressions according to the method in Li (1985) that more

[19] Gibbons and Murphy (1990) study relative performance evaluation in short-term compensation and find larger negative effects of industry performance on compensation when they define the industry more broadly (e.g., at the market or one-digit SIC level rather than at the three- or four-digit SIC level). Since strategic interactions in product markets decrease as the product market includes progressively less substitutable products, this pattern of results is consistent with a model that has elements of both relative performance evaluation and Bertrand competition.

systematically reduces the impact of outliers by weighting observations in proportion to their proximity to the mean value of the dependent variable. The results are again similar to those in Table III.

Equations (37) and (39) control for industry, firm, and executive characteristics that might affect both firm performance and compensation through the inclusion of industry effects and executive fixed effects. Previous studies have identified several factors that are known to influence executive compensation.[20] We control for these factors directly by augmenting equation (37) with the following regressors: sales in millions of dollars; research and development (R&D) expense as a percentage of sales (see Clinch (1991)); net property, plant, and equipment as a percentage of book value of assets; the market-to-book ratio of assets; the standard deviation of firm stock returns; a dummy variable for whether the executive is on the board of directors; and the number of times the board meets annually.[21]

The results of these augmented regressions are reported in Table V for both the median and OLS specifications for total compensation. As expected, the R-squared for the augmented regressions is higher relative to the left two columns of Table III, Panel A, and Table IV, Panel A. As is well known, firm size (sales) is positively related to compensation. We find that R&D intensity (the ratio of R&D to sales) is insignificant. Asset tangibility is generally significant when specified as the ratio of PPE to assets but is always insignificant when specified as the market-to-book ratio. We find that compensation is negatively related to the standard deviation of firm returns, negatively related to whether the executive is on the board of directors, and positively related to how frequently the board meets. Most importantly, the inclusion of these control variables does not change our main results. The own and rival pay-performance sensitivities are still positive and significant. The compensation ratio is still increasing in industry concentration, and the compensation ratio test is statistically significant at the 1 percent level in all specifications.[22]

Our model assumes that industry structure and concentration are exogenous to the choice of compensation contracts and strategic competition. One might be concerned that industry concentration is determined after the choice of compensation contracts. There are several reasons why we believe that

[20] See, for example, Bizjak, Brickley, and Coles (1993) and Murphy (1998).

[21] These variables are generated as follows. Information on sales and directorship is reported in ExecuComp. We compute the market-to-book ratio, the ratio of R&D to sales, and the ratio of property, plant, and equipment to assets from COMPUSTAT. We use CRSP data to compute the standard deviation of real monthly returns (including dividends and other distributions) over the five years preceding the year in which compensation is received.

[22] The results for the other two specifications are also similar to those in Panel A of Tables III and IV when the additional control variables are included. In particular, the rival-firm pay-performance sensitivity is positive and significant at the median industry concentration ratio and is decreasing in industry concentration (i.e., η_4 is negative and significant). As in Tables III and IV, the compensation ratio tests are typically positive though not always statistically significant.

Table IV

OLS Regressions of Pay-Performance Sensitivity

This table estimates OLS regressions of the pay-performance sensitivity based on the ExecuComp and Census of Manufactures datasets. The dependent variables are total compensation in Panel A and short-term compensation in Panel B. Each panel consists of three sets of regressions, corresponding to equations (37) through (39):

$$w_{ijt} = \eta_0 + \eta_1 \pi^o_{jt} + \eta_2 \pi^r_{jt} + \eta_3 F(H_j)\pi^o_{jt} + \eta_4 F(H_j)\pi^r_{jt} + \eta_5 F(H_j) + \eta_6 CEO_{it} + \sum_{k=21}^{39} \mu_{jk} + \sum_{t=94}^{95} \psi_t + \varepsilon_{ijt} \tag{37}$$

$$\Delta w_{ijt} = \eta_0 + \eta_1 \pi^o_{jt} + \eta_2 \pi^r_{jt} + \eta_3 F(H_j)\pi^o_{jt} + \eta_4 F(H_j)\pi^r_{jt} + \eta_5 F(H_j) + \eta_6 CEO_{it} + \sum_{t=94}^{95} \psi_t + \varepsilon_{ijt} \tag{38}$$

$$\Delta w_{ijt} = \eta_1 \Delta\pi^o_{jt} + \eta_2 \Delta\pi^r_{jt} + \eta_3 F(H_j)\Delta\pi^o_{jt} + \eta_4 F(H_j)\Delta\pi^r_{jt} + \eta_6 \Delta CEO_{it} + \sum_{t=94}^{95} \psi_t + \Delta\varepsilon_{ijt} \tag{39}$$

Each set of regressions is estimated once with product market rivals defined at the four-digit level and once with rivals defined at the three-digit level. All dollar values are in thousands (compensation) or millions (performance) of constant 1995 dollars. Coefficients for years and two-digit SICs (in equation (37)) are not reported. Standard errors are in parentheses under each coefficient. For the hypothesis tests, p-values are reported in brackets beneath each estimate.

Regression Coefficients	Dependent Variable in Levels (37)		Dependent Variable in Differences (38)		All Variables in Differences (39)	
	4-digit	3-digit	4-digit	3-digit	4-digit	3-digit
Panel A: Dependent Variable is Total Compensation						
Own performance (η_1)	−0.0206	−0.0578	0.0195	0.0888	0.0289	−0.0003
	(0.0264)	(0.0249)	(0.0329)	(0.0315)	(0.0229)	(0.0221)
Rival performance (η_2)	0.2195	0.2640	−0.0676	−0.0601	0.0519	0.0566
	(0.0283)	(0.0283)	(0.0381)	(0.0389)	(0.0218)	(0.0221)
Own performance × Herf. percentile (η_3)	0.1765	0.2616	−0.1213	−0.0429	−0.0690	0.0280
	(0.0391)	(0.0330)	(0.0467)	(0.0412)	(0.0322)	(0.0306)
Rival performance × Herf. percentile (η_4)	−0.1936	−0.2746	0.1308	0.0779	−0.0475	−0.0963
	(0.0388)	(0.0387)	(0.0505)	(0.0519)	(0.0285)	(0.0311)
Herfindahl percentile	408.9784	429.2175	132.6445	102.3970	—	—
	(68.1851)	(58.5164)	(63.2630)	(57.4435)		

CEO indicator	1155.3520	1153.7460	107.5119	93.6161	−125.8857	−97.8904
	(37.0862)	(34.3021)	(42.2519)	(39.4166)	(194.8699)	(176.2608)
Adjusted R^2	0.1844	0.1998	0.0135	0.0150	0.0036	0.0017
Number of observations	7793	8873	6198	7042	6044	6899
Hypothesis tests at the median industry concentration ratio ($F(H)$ = 0.5)						
Own performance	0.0677	0.0730	0.0488	0.0674	−0.0056	0.0137
[p-value]	[0.0000]	[0.0000]	[0.0007]	[0.0000]	[0.5915]	[0.1620]
Rival performance	0.1227	0.1268	−0.0022	−0.0211	0.0281	0.0084
[p-value]	[0.0000]	[0.0000]	[0.8992]	[0.2055]	[0.0081]	[0.4199]
Compensation ratio test	2.3085	3.3115	−1300.7222	−9.7159	−2.7959	21.9168
[p-value]	[0.0000]	[0.0000]	[0.9491]	[0.4245]	[0.0370]	[0.6942]
Panel B: Dependent Variable is Short-Term Compensation						
Own performance (η_1)	0.0181	0.0116	0.0155	0.0256	0.0244	0.0166
	(0.0092)	(0.0089)	(0.0057)	(0.0052)	(0.0043)	(0.0041)
Rival performance (η_2)	0.0545	0.0670	−0.0037	−0.0126	0.0007	0.0028
	(0.0099)	(0.0101)	(0.0061)	(0.0059)	(0.0039)	(0.0039)
Own performance × Herf. percentile (η_3)	0.0452	0.0547	0.0113	−0.0053	−0.0407	−0.0194
	(0.0137)	(0.0118)	(0.0084)	(0.0070)	(0.0061)	(0.0056)
Rival performance × Herf. percentile (η_4)	−0.0582	−0.0728	−0.0153	−0.0035	−0.0164	−0.0245
	(0.0136)	(0.0138)	(0.0083)	(0.0081)	(0.0052)	(0.0055)
Herfindahl percentile	153.1066	164.9943	55.0399	46.7433	—	—
	(23.8424)	(20.8679)	(12.3247)	(10.8375)		
CEO indicator	518.5024	520.7808	72.9198	72.3918	119.7745	138.8183
	(12.9678)	(12.2325)	(8.3226)	(7.5273)	(39.7099)	(35.0888)
Adjusted R^2	0.2449	0.2491	0.0323	0.0349	0.0371	0.0265
Number of observations	7794	8874	7182	8178	6972	7985
Hypothesis tests at the median industry concentration ratio ($F(H)$ = 0.5)						
Own performance	0.0407	0.0390	0.0211	0.0230	0.0040	0.0069
[p-value]	[0.0000]	[0.0000]	[0.0000]	[0.0000]	[0.0402]	[0.0002]
Rival performance	0.0254	0.0306	−0.0114	−0.0143	−0.0075	−0.0095
[p-value]	[0.0000]	[0.0000]	[0.0001]	[0.0000]	[0.0001]	[0.0000]
Compensation ratio test	5.4606	4.8129	1.4967	0.7584	6.6086	3.9541
[p-value]	[0.0029]	[0.0001]	[0.3206]	[0.3073]	[0.0007]	[0.0015]

Table V
Regressions of Pay-Performance Sensitivity with Additional Controls

This table estimates median and OLS regressions of the pay-performance sensitivity based on the ExecuComp and Census of Manufactures datasets. The dependent variable is the level of Total Compensation, so that the left and right sets of regressions correspond to the left two regressions of Panel A of Tables III (Median) and IV (OLS). Each regression augments equation (37) to include additional explanatory variables, denoted by the vector $\mathbf{Z}_{ijt}$ in the following equation:

$$w_{ijt} = \eta_0 + \eta_1 \pi^o_{jt} + \eta_2 \pi^r_{jt} + \eta_3 F(H_j)\pi^o_{jt} + \eta_4 F(H_j)\pi^r_{jt} + \eta_5 F(H_j) + \eta_6 CEO_{it} + \sum_{k=21}^{39} \mu_{jk} + \sum_{t=94}^{95} \psi_t + \xi' Z_{ijt} + \varepsilon_{ijt} \quad (37')$$

Each set of regressions is estimated once with product market rivals defined at the four-digit level and once with rivals defined at the three-digit level. All dollar values are in thousands (compensation) or millions (performance) of constant 1995 dollars. Coefficients for years and two-digit SICs are not reported. Standard errors are in parentheses under each coefficient. For the hypothesis tests, p-values are reported in brackets beneath each estimate.

Regression Coefficients	Median Regressions		OLS Regressions	
	4-digit	3-digit	4-digit	3-digit
Own performance (η_1)	0.0138	0.0002	−0.0354	−0.0637
	(0.0094)	(0.0079)	(0.0274)	(0.0260)
Rival performance (η_2)	0.0760	0.0824	0.1594	0.1846
	(0.0010)	(0.0090)	(0.0296)	(0.0298)
Own performance × Herf. percentile (η_3)	0.0543	0.05876	0.1132	0.1838
	(0.0139)	(0.0105)	(0.0406)	(0.0347)
Rival performance × Herf. percentile (η_4)	−0.0931	−0.0623	−0.1472	−0.1974
	(0.0137)	(0.0123)	(0.0403)	(0.0406)
Herfindahl percentile	43.4516	76.2099	294.6054	304.6400
	(27.3895)	(21.1380)	(79.3251)	(68.2666)
CEO indicator	794.3385	778.0820	1283.6070	1280.9370
	(14.8363)	(12.2525)	(42.9444)	(39.6022)
Sales	0.0365	0.0379	0.0264	0.0269
	(0.0006)	(0.0005)	(0.0016)	(0.0016)
R&D expenses/Sales	−0.0173	−0.0220	−0.0625	−0.0684
	(0.0200)	(0.0187)	(0.0615)	(0.0605)
Property, plant, & equip./Total assets	−1.9017	−2.5244	−2.0473	−4.6671
	(0.5011)	(0.4073)	(1.4524)	(1.3156)
Market-to-book ratio of assets	−5.0467	0.5312	−2.1862	−4.7970
	(5.5446)	(4.7114)	(16.0793)	(15.2328)
Standard deviation of firm returns	−29.0937	−29.8491	−43.1088	−44.1348
	(1.8864)	(1.5807)	(5.4734)	(5.1199)
Executive is a director of firm	−147.3762	−142.0282	−335.1323	−366.3114
	(30.1258)	(23.4573)	(87.5834)	(76.1782)
Number of annual meetings of the board	29.2094	29.3910	47.3004	47.3115
	(2.4956)	(2.0877)	(7.2296)	(6.7458)
R^2	0.2289	0.2292	0.2568	0.2732
Number of observations	6045	6911	6045	6911
Hypothesis tests at the median industry concentration ratio ($F(H) = 0.5$)				
Own performance	0.0410	0.0296	0.0212	0.0282
[p-value]	[0.000]	[0.000]	[0.094]	[0.018]
Rival performance	0.0294	0.0512	0.0858	0.0859
[p-value]	[0.000]	[0.000]	[0.000]	[0.000]
Compensation ratio test	6.2497	1.8517	1.7436	2.8934
[p-value]	[0.0009]	[0.0000]	[0.0049]	[0.0000]

this is not a major concern for our empirical work. First, our measure of compensation is annual flow compensation. This is a variable that is adjusted on a yearly basis. In contrast, entry and exit decisions of firms (i.e., changes in industry concentration) are multiyear, long-term decisions that are not adjusted frequently. Second, our measure of industry concentration is proxying for product differentiation. In our sample, we look only at manufacturing firms, where the degree of product differentiation is likely to be a long-term choice. Third, in our empirical implementation, we regress compensation on industry concentration as of 1992, the most recent survey year of the Census of Manufactures prior to the beginning of the ExecuComp sample. In this framework, industry concentration is determined prior to compensation.

Another possible explanation for our findings is that industry concentration is proxying for another determinant of compensation that varies across industries. This alternative explanation would have to generate a positive industry pay-performance sensitivity as well as a compensation ratio that is increasing in industry concentration. One possibility is that in more concentrated industries there is lower correlation between firm returns and industry returns. If both firm and industry returns are informative about the manager's unobserved or noncontractible action choice, then executives in more concentrated industries will have less relative weight placed on industry performance. The effect of industry concentration will be due to the correlation between firm and industry returns and not strategic competition.

In order to examine this possibility, we look directly at the correlation between firms' stock returns and industry returns. We compute this correlation at both the three- and four-digit SIC levels. If the correlation between firm and industry returns is driving our results, we expect to find a negative association between industry concentration and this correlation. Instead, we find this association to be positive but insignificant. We also estimate our regressions (not reported) with three additional explanatory variables included: the correlation between firm and industry returns, this correlation interacted with own-firm performance, and this correlation interacted with rival-firm performance. Our main results are robust to the inclusion of these variables. The estimated coefficients of these additional variables show little evidence of a separate effect due to the correlation between firm and industry returns.

Thus far, we have defined total compensation as the annual flow of resources that the shareholders could have kept for themselves had they not used it to compensate the executive. If an executive owns stock in her firm or her rival firm, then her incentives come from not only her flow rate of compensation but any change in the value of her personal stock holdings that result from her actions.[23] Recognizing this, the shareholders of her firm can incorporate lower pay-performance sensitivities into her annual compensation contract. Conditional on a particular allocation of the executive's per-

[23] Of the overall \$3.25 per thousand that Jensen and Murphy (1990) estimate for the pay-performance sensitivity, \$2.50 is related to changes in wealth due to stockholdings.

sonal wealth, the relationship between product substitutability and the compensation ratio takes the same form as in the models of Sections I and II. Since we do not have data on the executive's holdings of her rival firms, we cannot test our predictions directly. In order to test for the robustness of our findings to the incentives provided by inside ownership, we stratify our sample into two groups of executives: those with less than the median wealth in their own firm at the beginning of the sample year (approximately $565,000) and those with more than the median. We then estimate the regressions from Table III, Panel A, with the level of compensation as the dependent variable.

The results of these regressions are presented in Table VI. The estimates of the own and rival pay-performance sensitivities are positive and significant at the median industry concentration ratio. Further support for the Bertrand model comes from the negative estimates of η_4. The compensation ratio test restriction is positive and significant for both regressions in the High Ownership group and for the four-digit SIC regression in the Low Ownership group. The test restriction is positive but insignificant for the three-digit regression in the Low Ownership group. Additionally, the magnitudes of the pay-performance sensitivities across the groups are consistent with our framework. The sensitivities are higher in the Low Ownership group, suggesting that the pay-performance sensitivities in the flow of payments to the executives take into account the executives' personal portfolio holdings. The results in Table VI show that our main findings are robust to differences in executives' inside ownership.

V. Conclusion

We derive the optimal contracts in a principal-agent model of strategic competition in which managers can be compensated on both their own profits and their rival's (or industry) profits. We demonstrate that when competition is differentiated Bertrand, the optimal contract compensates the manager positively on both own- and rival-firm performance. This contract has the effect of softening competition. We show that the ratio of compensation based on own-firm performance to that based on rival-firm performance is decreasing in the degree of competition in the industry. The need to soften competition is highest in those industries that are most competitive. Relative performance evaluation, the natural consequence of the principal-agent framework, lowers returns to shareholders. When competition is differentiated Cournot, the optimal contract compensates the manager positively on own-firm performance and negatively on rival-firm performance. This contract intensifies competition and lowers profits for both firms. Such contracts resemble relative performance evaluation, but the impetus for their use comes from the nature of competition, not an agency problem. The appendixes show that our theoretical results continue to hold in a fully specified principal-agent model and in a model in which compensation contracts are not publicly observable.

Table VI

Median Regressions of Pay-Performance Sensitivity, Stratified by Inside Ownership

This table estimates median regressions of the pay-performance sensitivity based on the ExecuComp and Census of Manufactures datasets. Separate estimates are provided for executives with inside ownership of their firms below and above the sample median of $565,000. The dependent variable is the level of total compensation, so that the regressions correspond to the left two regressions of Panel A of Table III. Each regression is based on equation (37):

$$w_{ijt} = \eta_0 + \eta_1 \pi^o_{jt} + \eta_2 \pi^r_{jt} + \eta_3 F(H_j)\pi^o_{jt} + \eta_4 F(H_j)\pi^r_{jt} + \eta_5 F(H_j) + \eta_6 CEO_{it} + \sum_{k=21}^{39} \mu_{jk} + \sum_{t=94}^{95} \psi_t + \varepsilon_{ijt} \tag{37}$$

Each set of regressions is estimated once with product market rivals defined at the four-digit level and once with rivals defined at the three-digit level. All dollar values are in thousands (compensation) or millions (performance) of constant 1995 dollars. Coefficients for years and two-digit SICs are not reported. Standard errors are in parentheses under each coefficient. For the hypothesis tests, p-values are reported in brackets beneath each estimate.

	Low Inside Ownership		High Inside Ownership	
Regression Coefficients	4-digit	3-digit	4-digit	3-digit
Own performance (η_1)	0.0655	0.1365	0.0472	0.0166
	(0.0249)	(0.0217)	(0.0264)	(0.0244)
Rival performance (η_2)	0.2198	0.1974	0.1449	0.2024
	(0.0333)	(0.0277)	(0.0303)	(0.0298)
Own performance × Herf. percentile (η_3)	0.1813	0.0498	0.1211	0.1365
	(0.0371)	(0.0337)	(0.0375)	(0.0313)
Rival performance × Herf. percentile (η_4)	−0.1083	−0.0071	−0.1712	−0.1606
	(0.0454)	(0.0411)	(0.0393)	(0.0393)
Herfindahl percentile	120.8905	156.6239	307.4903	290.6312
	(37.2189)	(28.7353)	(84.0893)	(66.2210)
CEO indicator	691.9724	634.2496	678.1868	695.2444
	(32.4345)	(26.4449)	(37.9645)	(32.6640)
Pseudo R^2	0.1238	0.1255	0.1136	0.1229
Number of observations	2491	2831	2492	2832
Hypothesis tests at the median industry concentration ratio ($F(H) = 0.5$)				
Own performance	0.1561	0.1614	0.1077	0.0848
[p-value]	[0.0000]	[0.0000]	[0.0000]	[0.0000]
Rival performance	0.1657	0.1938	0.0593	0.1221
[p-value]	[0.0000]	[0.0000]	[0.0000]	[0.0000]
Compensation ratio test	1.7097	0.2872	7.2875	2.0318
[p-value]	[0.0000]	[0.3759]	[0.0099]	[0.0000]

Our theoretical results are similar to those found in the literature on capital structure choice and product market competition (Bolton and Scharfstein (1990), Rotemberg and Scharfstein (1990), Maksimovic (1988), and Brander and Lewis (1986)). In those papers, debt serves to precommit managers to either more aggressive or less aggressive product market behavior.

Generally, when competition is in strategic substitutes, debt induces more aggressive product market behavior and lower profits in equilibrium. When competition is in strategic complements, debt induces less aggressive product market behavior and higher profits in equilibrium. The results are similar when own- and rival-firm compensation contracts are the precommitment device.

Our empirical findings are consistent with the predictions from our differentiated Bertrand model. The rival-firm pay-performance sensitivity is positive and significant in most specifications. The ratio of the own-firm to rival-firm pay-performance sensitivities decreases as the industry becomes more competitive. In some specifications with short-term compensation as the dependent variable, we find a negative rival pay-performance sensitivity, which is consistent with a relative performance evaluation model. In these specifications, we also find that the compensation of executives in more competitive industries exhibits less relative performance evaluation, as the logic of the differentiated Bertrand model suggests. Overall, we find that the extent of relative performance evaluation is limited by strategic interactions.

Our work may provide an explanation of the results of Jensen and Murphy (1990) who find a low own-firm pay-performance sensitivity. Our models predict that it is the ratio of the own-firm to rival-firm pay-performance sensitivities that determines incentives. The optimal contract in the presence of strategic competition requires a positive own-firm pay-performance sensitivity, but it can be small as long as the rival-firm pay-performance sensitivity is of a similar magnitude. In general, if the return to effort or the cost of effort is negligible, then there is no reason to provide high-powered incentives to risk-averse managers. A low own-firm pay-performance sensitivity may therefore be consistent with a principal-agent model that includes strategic interactions among firms in imperfectly competitive markets.[24]

More importantly, our work shows why relative performance evaluation is not a more prominent feature of executive compensation contracts. Though the literature has long recognized the risk-sharing benefits of relative performance evaluation, our results suggest that there are also unambiguous costs. Pay based on relative performance gives executives incentives to lower industry performance by pricing too aggressively in a differentiated Bertrand model. Shareholders' wealth increases when the compensation contract rewards the manager for not undercutting her rivals in the product market. Our model shows that when contracts can be based on own- and rival-firm performance, this reward comes through a positive rival-firm pay-performance sensitivity.

[24] There are many potential explanations for the Jensen and Murphy (1990) result. For example, Narayanan (1985), Stein (1989), and Bizjak et al. (1993) all show that compensation contracts that focus on short-term stock price performance can lead to underinvestment, and so such contracts are not optimal. These papers offer an explanation for a low own-firm pay-performance sensitivity, but they do not explain a positive industry pay-performance sensitivity or a compensation ratio that is increasing in industry concentration.

When interpreting empirical results on relative performance evaluation, it is important to recognize that there is an inherent conflict between strategic competition and the principal-agent problem. The standard principal-agent model ignores the importance of strategic competition in product markets to the value of the firm. Our empirical work shows that the use of relative performance evaluation will be tempered by the degree of competition in a firm's industry. We therefore offer an explanation for the infrequent use of relative performance evaluation – it is typically not optimal for shareholders.

Appendix A. Fully Integrated Principal-Agent Model

We use the linear principal-agent model of Holmström and Milgrom (1987) to create a full principal-agent model that incorporates an effort choice, a disutility of effort, a common shock, and risk aversion in addition to strategic competition. The timing of this model is that at stage 0, contracts are signed and then revealed. At stage 1, agents simultaneously make effort and product market choices. At stage 2, profits are realized and agents are paid according to their contracts. In this model, the agent's effort choice and product-market choice are unobservable to the principal but are observable to the rival.

The agent's compensation is

$$w_i = k_i + \alpha_i \pi_i + \beta_i \pi_j, \tag{A1}$$

where

$$\pi_i = (p_i - c)(A - bp_i + ap_j) + te_i + \varepsilon. \tag{A2}$$

This is the same profit function as in Section I of the paper augmented with the term te_i which captures the agent's effort e_i and the marginal return to effort t.

We assume that the agent has exponential utility and that the noise term ε (a common shock) is normally distributed with mean 0 and variance σ^2. The agent's certainty equivalent is

$$u_i = w_i - \frac{s}{2} e_i^2 - \frac{r}{2} (\alpha_i + \beta_i)^2 \sigma^2, \tag{A3}$$

where s parameterizes the cost of the agent's effort and r is the agent's coefficient of absolute risk aversion. We assume that managers (agents) face a competitive labor market. Therefore, the agent's individual rationality constraint, which is met with equality, can be written in certainty equivalent terms as

$$w_i - \frac{s}{2} e_i^2 - \frac{r}{2} (\alpha_i + \beta_i)^2 \sigma^2 \geq u_i', \tag{A4}$$

which implies that

$$w_i = \frac{s}{2} e_i^2 + \frac{r}{2} (\alpha_i + \beta_i)^2 \sigma^2 + u_i'. \tag{A5}$$

The agent's maximization problem can be written as

$$\begin{aligned} \max_{e_i, p_i} \alpha_i((p_i - c)(A - bp_i + ap_j) + te_i) \\ + \beta_i((p_j - c)(A - bp_j + ap_i) + te_j) \\ - \frac{s}{2} e_i^2 - \frac{r}{2} (\alpha_i + \beta_i)^2 \sigma^2. \end{aligned} \tag{A6}$$

The agents' optimal price and effort choices as functions of contracts are

$$p_i^{**} = \frac{-\alpha_j A(\alpha_i a + 2b\alpha_i + \beta_i a) - \alpha_j bc(2b\alpha_i + \alpha_i a - \beta_i a) + a^2 c\beta_j(\alpha_i + \beta_i)}{-4\alpha_i b^2 \alpha_j + \alpha_i a^2 \alpha_j + \alpha_i a^2 \beta_j + \beta_i a^2 \alpha_j + \beta_i a^2 \beta_j},$$

$$e_i^{**} = \frac{t}{s} \alpha_i. \tag{A7}$$

The agents' optimal price choices are the same function of contracts that we derive in Section I where there is no risk aversion or effort choice. This is because we assume that effort is additively separable from product market choices. Further, constant absolute risk aversion (CARA) utility implies that there are no wealth effects from either effort choices or product market choices. Hence, neither risk aversion nor the effort choice affects the price choice.

The principal's expected profit maximization problem after substituting for the agent's wage is

$$\max_{\alpha_i, \beta_i} (p_i - c)(A - bp_i + ap_j) + te_i - \frac{s}{2} e_i^2 - \frac{r}{2} (\alpha_i + \beta_i)^2 \sigma^2 - u_i'. \tag{A8}$$

The first-order conditions of the principal's profit maximization problem with respect to α_i and β_i are

$$\begin{aligned} \alpha_j(ca + A - bc)^2 a^2 \beta_i(2b\alpha_j + \alpha_j a + \beta_j a) z_i + \frac{t^2}{s} - \frac{t^2}{s} \alpha_i - r(\alpha_i + \beta_i)\sigma^2 = 0, \\ -\alpha_j a^2 (ca + A - bc)^2 \alpha_i (2b\alpha_j + \alpha_j a + \beta_j a) z_i - r(\alpha_i + \beta_i)\sigma^2 = 0, \end{aligned} \tag{A9}$$

where

$$z_i = \frac{\beta_j a^2\beta_i + \alpha_j a^2\alpha_i + \alpha_j a^2\beta_i + \beta_j a^2\alpha_i + 2\alpha_j a\alpha_i b - 2a\beta_i b\alpha_j + 2\alpha_i b\beta_j a - 2ab\beta_j\beta_i - 4\beta_i b^2\alpha_j}{(-4\alpha_i b^2\alpha_j + \alpha_i a^2\alpha_j + \alpha_i a^2\beta_j + \beta_i a^2\alpha_j + \beta_i a^2\beta_j)^3}. \tag{A10}$$

Because the game is symmetric, there exists a symmetric equilibrium. We reduce the system of four equations and four unknowns to two equations and two unknowns by substituting $\alpha = \alpha_j = \alpha_i$ and $\beta = \beta_j = \beta_i$ to get

$$\begin{aligned} &a^2\alpha(ca + A - bc)^2\beta\,\frac{\alpha a + \beta a - 2b\beta}{(\alpha a + \beta a - 2\alpha b)^3(\alpha a + \beta a + 2\alpha b)} \\ &\quad + \frac{t^2}{s}(1-\alpha) - r\sigma^2(\alpha+\beta) = 0, \\ &-a^2\alpha^2(ca + A - bc)^2\,\frac{\alpha a + \beta a - 2b\beta}{(\alpha a + \beta a - 2\alpha b)^3(\alpha a + \beta a + 2\alpha b)} \\ &\quad - r\sigma^2(\alpha+\beta) = 0. \end{aligned} \tag{A11}$$

An analytic solution to these two equations is not possible because each involves a fifth-order polynomial. But we can solve them numerically to generate comparative statics. The following contract characteristics and comparative statics are true for the product market. The optimal contracts will put positive weight on both the own and rival firms, $\alpha^{**} \in (0,1]$, $\beta^{**} \in (0,1)$, except when $a = 0$. When $a = 0$, the firm has a monopoly and product market considerations are irrelevant. In this case, the unique contract is $\{\alpha^{**} = 1, \beta^{**} = -1\}$, which is a relative performance evaluation contract that completely filters out the common shock ε. Relative to the analysis of Section I, at $a = 0$ we have a discontinuity that generates relative performance evaluation.

The central comparative static result of Section I remains unchanged:

$$\partial\left(\frac{\alpha^{**}}{\beta^{**}}\right)\Big/\partial\left(\frac{b}{a}\right) > 0. \tag{A12}$$

As the product market becomes more differentiated, more weight is put on the own firm relative to the rival firm in the optimal contract. The components of the optimal contracts are well behaved as the degree of product substitutability changes:

$$\frac{\partial\alpha^{**}}{\partial\left(\dfrac{b}{a}\right)} > 0, \qquad \frac{\partial\beta^{**}}{\partial\left(\dfrac{b}{a}\right)} < 0. \tag{A13}$$

The following comparative statics are true for risk:

$$\frac{\partial \alpha^{**}}{\partial r} < 0, \qquad \frac{\partial \beta^{**}}{\partial r} < 0, \qquad \frac{\partial \alpha^{**}}{\partial \sigma^2} < 0, \qquad \frac{\partial \beta^{**}}{\partial \sigma^2} < 0. \tag{A14}$$

As the agent becomes more risk averse or as the variance of the common shock increases, the agent's incentives become lower powered. But note that it is not the case that we see relative performance evaluation, $\beta^{**} < 0$, as the agent becomes more risk averse or the variance of the common shock increases. If either $r = 0$ or $\sigma^2 = 0$ (i.e., there is no effect of risk), then the optimal contracts are: $\{\alpha^{**} = 1, \beta^{**} = a/(2b - a)\}$.

The following comparative statics are true for the effort choice:

$$\frac{\partial \alpha^{**}}{\partial t} > 0, \qquad \frac{\partial \beta^{**}}{\partial t} > 0, \qquad \frac{\partial \alpha^{**}}{\partial s} < 0, \qquad \frac{\partial \beta^{**}}{\partial s} < 0. \tag{A15}$$

As the return to effort increases or the cost of effort decreases, the weights on the own firm and the rival increase. When $t = 0$ (i.e., there are no returns to effort) then there does not exist an interior equilibrium. The solution is to choose $\alpha^{**} > 0$, $\beta^{**} > 0$ but both as small as possible to mitigate risk. The relationship between α^{**} and β^{**} is $\alpha^{**}/\beta^{**} = (2b - a)/a$. The same result holds if $s = 0$. When there is no cost of effort, the agent provides as much effort as possible for any positive contract. In both cases, the contract has no effect on the effort choice.

Appendix B. Unobservability and Signaling

Here we construct a signaling game for the Bertrand case that eliminates the need for observable contracts as a commitment device. Our purpose is not to provide a general model of signaling by an agent (see Caillaud and Hermalin (1993)), but rather to demonstrate that contract observability is a dispensable part of the model of Section I. We assume that contracts and signals are one-sided. Only one manager (the manager of firm 1) can be given an own and rival contract, and this manager must then choose whether or not to signal that she has been given such a contract. Her rival manager (the manager of firm 2) is not given an own and rival contract and cannot signal anything. This assumption on the manager of firm 2 is immaterial—we make it to simplify the exposition. Note that we are departing from our previous assumption of symmetry. If we restore symmetry, the results of this appendix will generalize, but at the cost of additional complexity. We also revert to the assumption of Section I that the managers are risk neutral.

The timing of the model is that at stage 0, unobservable contracts are signed between principals and agents. At stage 1, the manager of firm 1 takes an action choice that is fully observable and that may signal her contract. At stage 2, there is product market competition, profits are realized, and agents are paid according to their contracts. In our analysis, signaling occurs through the agent's action choice in stage 1. This unspecified action choice could be an investment decision, another stage of product market competition, or any other variable that is under the control of the agent and is costly to the agent.

Our strategy in this appendix is to provide sufficient conditions for an own and rival contract to emerge as a separating equilibrium in a signaling game. We first derive optimal contracts for the case where the managers are compensated strictly on own-firm performance. Then we derive the optimal contracts when the manager of firm 1 is compensated on own and rival performance but the manager of firm 2 is compensated strictly on own-firm profits. For this derivation, we assume that contracts are observable. Last we show how a contract equivalent to this second, observable contract can be sustained as a separating equilibrium when contracts are unobservable.

Suppose managers are compensated strictly on own-firm profits:

$$w_i = k_i + \lambda_i((p_i - c)(A - bp_i + ap_j) + \varepsilon). \tag{B1}$$

The reaction functions are

$$R_i(p_j) = \frac{A + bc + ap_j}{2b}. \tag{B2}$$

Equilibrium prices and profits are given by equations (3) and (4) in the text. The principal's choice of optimal contract for the agent satisfies $\lambda_i^* > 0$.

Next, we solve the contractual game with full observability. In this case, only the manager of firm 1 is given an own and rival contract, and the managers solve

$$\begin{aligned} &\max_{p_1} \alpha_1((p_1 - c)(A - bp_1 + ap_2) + \varepsilon) + \beta_1((p_2 - c)(A - bp_2 + ap_1) + \varepsilon), \\ &\max_{p_2} \alpha_2((p_2 - c)(A - bp_2 + ap_1) + \varepsilon). \end{aligned} \tag{B3}$$

The reaction functions are

$$\begin{aligned} R_1'(p_2) &= \frac{A + bc + ap_2}{2b} + \frac{\beta_1 ap_2 - \beta_1 ac}{2\alpha_1 b}, \\ R_2'(p_1) &= \frac{A + bc + ap_1}{2b}, \end{aligned} \tag{B4}$$

and price choices as functions of contracts are

$$p_1^{**} = \frac{A(\alpha_1 a + 2b\alpha_1 + \beta_1 a) + bc(2b\alpha_1 + \alpha_1 a - \beta_1 a)}{4\alpha_1 b^2 - \alpha_1 a^2 - \beta_1 a^2},$$
$$p_2^{**} = \frac{\alpha_1 A(2b + a) + c(2\alpha_1 b^2 - \beta_1 a^2 + \alpha_1 ab)}{4\alpha_1 b^2 - \alpha_1 a^2 - \beta_1 a^2}. \tag{B5}$$

The principal of firm 1 maximizes:

$$\max_{\alpha_1, \beta_1} E[\pi_1] - w_1' = (p_1^{**} - c)(A - bp_1^{**} + ap_2^{**}) - w_1'. \tag{B6}$$

The first-order conditions are

$$\beta_1 a^2(2b + a)(ca + A - bc)^2 \frac{\alpha_1 a^2 + \beta_1 a^2 - 2b\beta_1 a + 2\alpha_1 ab - 4b^2\beta_1}{(-4\alpha_1 b^2 + \alpha_1 a^2 + \beta_1 a^2)^3} = 0,$$
$$-\alpha_1 a^2(2b + a)(ca + A - bc)^2 \frac{\alpha_1 a^2 + \beta_1 a^2 - 2b\beta_1 a + 2\alpha_1 ab - 4b^2\beta_1}{(-4\alpha_1 b^2 + \alpha_1 a^2 + \beta_1 a^2)^3} = 0. \tag{B7}$$

The equilibrium contracts are

$$\left\{\alpha_1^{**} = y, \beta_1^{**} = a\,\frac{2b + a}{-a^2 + 2ba + 4b^2}\,y, y \in \Re^+\right\}$$

and

$$\{\alpha_2^{**} > 0\}.$$

Equilibrium prices for both firms and profits for firm 1 are

$$p_1^{**} = \frac{1}{2}\,\frac{-ca^2 + acb + aA + 2cb^2 + 2Ab}{(2b^2 - a^2)},$$
$$p_2^{**} = \frac{1}{4}\,\frac{-ca^3 - a^2A - cba^2 + 2Aab + 2cb^2a + 4cb^3 + 4Ab^2}{(2b^2 - a^2)b}, \tag{B8}$$
$$E[\pi_1^{**}] = \frac{1}{8}(2b + a)^2\,\frac{(ca + A - bc)^2}{(2b^2 - a^2)b}.$$

The compensation ratio for this contract is

$$\frac{\alpha_1^{**}}{\beta_1^{**}} = \frac{4b^2 + 2ba - a^2}{a(a + 2b)}, \tag{B9}$$

and algebraic manipulation shows that the compensation ratio is still increasing in the degree of product differentiation: $\partial(\alpha_1^{**}/\beta_1^{**})/\partial(b/a) > 0$.

Now we construct a signaling game to generate sufficient conditions for the contracts just derived to be part of a separating equilibrium when contracts are unobservable. If the manager wants to signal that she has a contract based on own and rival performance,

$$\left\{\alpha_1^{**} = y, \beta_1^{**} = a\,\frac{2b + a}{-a^2 + 2ba + 4b^2}\,y, y \in \Re^+\right\},$$

she chooses an action of cost I^S (to her) where $I^S \in [0,\infty)$. If she does not want to signal that she has an own and rival contract (she has an own contract only, $\lambda_1^* > 0$), she chooses an action of cost I^{NS} (to her) where $I^{NS} \in [0,\infty)$.

The incentive compatibility constraints are

$$\begin{aligned} &k_1^{**} + \alpha_1^{**}\pi_1(p_1^{**},p_2^{**}) + \beta_1^{**}\pi_2(p_1^{**},p_2^{**}) - I^S \\ &\quad \geq k_1^{**} + \alpha_1^{**}\pi_1(R_1'(E(p_2|I = I^{NS})),E(p_2|I = I^{NS})) \\ &\quad + \beta_1^{**}\pi_2(R_1'(E(p_2|I = I^{NS})),E(p_2|I = I^{NS})) - I^{NS}, \end{aligned} \tag{B10}$$

and

$$k_1^* + \lambda_1^*\pi_1(p_1^*,p_2^*) - I^{NS} \geq k_1^* + \lambda_1^*\pi_1(R_1(E(p_2|I = I^S)),E(p_2|I = I^S)) - I^S. \tag{B11}$$

It follows immediately that the expected price charged by firm 2 conditional on seeing an action of cost I^S is the price firm 2 charges when the manager of firm 1 has an own and rival contract:

$$E(p_2|I = I^S) = p_2^{**}, \tag{B12}$$

and the expected price charged by firm 2 conditional on seeing an action of cost I^{NS} is the price firm 2 charges when the manager of firm 1 has an own-firm contract only:

$$E(p_2|I = I^{NS}) = p_2^*. \tag{B13}$$

Direct computation shows that

$$R_1'(p_2^*) = \frac{1}{2}\,\frac{Aa^3 + 4Ab^2a + 8Ab^3 - 4cb^2a^2 + cba^3 + 4cab^3 + 8cb^4 + ca^4}{(-2b + a)b(a^2 - 2ba - 4b^2)} \tag{B14}$$

and

$$R_1(p_2^{**}) = \frac{1}{8}\,\frac{-2Aa^2b + 8Ab^3 - 2cb^2a^2 + 8cb^4 - ca^4 - Aa^3 - cba^3 + 4cab^3 + 4Ab^2a}{(2b^2 - a^2)b^2}. \tag{B15}$$

After substituting and eliminating the noise term and the k_1^{**} term from both sides of the constraint, the first incentive compatibility constraint reduces to

$$\frac{1}{16}\,\alpha_1^{**}(ca + A - bc)^2a^4\,\frac{-64b^4a^2 - 56a^3b^3 + 20b^2a^4 + 128b^6 + 128ab^5 - 7a^6}{b(a^2 - 2b^2)^2(a^2 - 2ba - 4b^2)^2(-2b + a)^2} \geq I^S - I^{NS}. \tag{B16}$$

Because $b > a$, the left-hand side of the constraint is greater than zero.

After substituting and eliminating the noise term and the k_1^* term from both sides of the constraint, the second incentive compatibility constraint reduces to

$$I^S - I^{NS} \geq \frac{1}{64}\,\lambda_1^*(ca + A - bc)^2a^4\,\frac{a^4 + 32b^4 - 16b^2a^2}{(a^2 - 2b^2)^2b^3(-2b + a)^2}. \tag{B17}$$

Because $b > a$, the right-hand side of the constraint is greater than zero, implying that a necessary condition for separation is $I^S > I^{NS}$. In order for both constraints to be satisfied,

$$\frac{1}{16}\,\alpha_1^{**}(ca + A - bc)^2a^4\,\frac{-64b^4a^2 - 56a^3b^3 + 20b^2a^4 + 128b^6 + 128ab^5 - 7a^6}{b(a^2 - 2b^2)^2(a^2 - 2ba - 4b^2)^2(-2b + a)^2} > \frac{1}{64}\,\lambda_1^*(ca + A - bc)^2a^4\,\frac{a^4 + 32b^4 - 16b^2a^2}{(a^2 - 2b^2)^2b^3(-2b + a)^2}, \tag{B18}$$

which implies that

$$\frac{\alpha_1^{**}}{\lambda_1^*} > \frac{(a^4 + 32b^4 - 16b^2a^2)(a^2 - 2ba - 4b^2)^2}{4b^2(-64b^4a^2 - 56a^3b^3 + 20b^2a^4 + 128b^6 + 128ab^5 - 7a^6)}. \tag{B19}$$

The right-hand side of this inequality is greater than zero but less than one, implying that a lower bound for the share of the own firm in the own and rival contract is that the share be not much less than the share given to a manager with an own-firm contract only. Thus, a separating equilibrium that fully reveals the agent's contract is feasible from the agent's perspective even though contracts are unobservable.

Last, we must check that such a separating equilibrium is optimal for the principal as well. Because the principal keeps the agent on her individual rationality constraint, the principal must internalize the cost of the signal.

Thus the agent will only signal if it is optimal for the principal and incentive compatible for the agent, as shown above. The principal's net profit from an own and rival contract,

$$E[\pi_1^{**}] - w_1' - I^S, \tag{B20}$$

must be greater than the principal's net profit from an own-only contract,

$$E[\pi_1^{*}] - w_1' - I^{NS}. \tag{B21}$$

After substituting, the condition becomes

$$\frac{1}{8}(ca + A - bc)^2 \frac{a^4}{(2b^2 - a^2)b(-2b + a)^2} \geq I^S - I^{NS}. \tag{B22}$$

To ensure that principal optimality does not conflict with agent incentive compatibility, it must be the case that

$$\begin{aligned} &\frac{1}{8}(ca + A - bc)^2 \frac{a^4}{(2b^2 - a^2)b(-2b + a)^2} \\ &\quad \geq \frac{1}{64}\lambda_1^*(ca + A - bc)^2 a^4 \frac{a^4 + 32b^4 - 16b^2a^2}{(a^2 - 2b^2)^2 b^3(-2b + a)^2}, \end{aligned} \tag{B23}$$

or

$$\lambda_1^* \leq \frac{16b^4 - 8b^2a^2}{32b^4 - 16b^2a^2 + a^4}. \tag{B24}$$

Therefore, as long as the optimal choice of $\lambda_1^* \leq (16b^4 - 8b^2a^2/32b^4 - 16b^2a^2 + a^4)$, the principal chooses to give the agent an own and rival contract and the agent signals that she has such a contract.[25] Conversely, if the optimal choice of $\lambda_1^* > (16b^4 - 8b^2a^2)/(32b^4 - 16b^2a^2 + a^4)$, then an own-firm only contract is optimal. The optimal λ_1^* is exogenous to the signaling model (our only product market restriction is $\lambda_1^* > 0$)—λ_1^* can be pinned down by adding an effort choice or risk aversion or some other consideration.

[25] One other point to note is that the principal will not give the agent a λ_1^* contract and an extra amount I^S to induce the agent to falsely signal that she has an $(\alpha_1^{**}, \beta_1^{**})$ contract. Although this would be more profitable for the principal, once the agent has received the contract and the money, she will not falsely signal because it is not incentive compatible for her to do so. Therefore, the principal will not provide I^S in the first place.

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