

Oligopoly, Disclosure, and Earnings Management

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ABSTRACT: We examine how biased financial reports (managed earnings) affect product market competition and how product market competition affects incentives to bias financial reports in a model with fully rational firms. We find that Cournot competitors bias their reports to create the impression that their costs are lower than they actually are. This bias leads to lower total production and a higher product price, even though each firm fully understands its rival's incentives to bias its financial reports. The magnitude of the bias is larger when firms compete in more profitable product markets and smaller when the firm can extract more information about its rival's costs from its own. When the costs of misreporting are asymmetric, the lower-cost firm engages in more earnings management than its rival, produces more than it would in a full-information environment, and earns greater profits. Our analysis leads to new, testable relations among earnings management, reported and actual earnings, and industry structure.

Keywords: *earnings management; reporting bias; product market competition; information asymmetry.*

JEL Classifications: *G1; G14; M41.*

I. INTRODUCTION

We develop a theoretical model to examine how earnings management affects product market competition and how competition affects earnings management decisions. A key feature of our analysis is that, in addition to an information extraction problem, there is an important component of rivalry in the firms' earnings management and production decisions. The motivation for our study arises, in part, from claims made by C. Michael Armstrong who was CEO of AT&T from 1997 to 2002, one of the most turbulent times for the company. He has recently argued that accounting fraud at WorldCom was the cause of AT&T's *perceived*

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strategic failures, its inability to compete with WorldCom and, in the end, the decision to break up the company. He specifically suggests that WorldCom's fraudulently reported revenues, margins and costs drove AT&T's layoffs, cost-cutting, and a very unprofitable price war that left AT&T unable to service the debt he incurred to revive the company. This view is supported by William Estry who was Sprint's CEO during that same time.¹

To address our research questions, we employ an incomplete information Cournot duopoly model in which each firm knows its own production costs, but not its rival's. In our model, each firm provides a disclosure through, for example, its income statement. A firm's rival can use the disclosure to update its beliefs about the disclosing firm's production costs prior to competing in the product market. Our model differs from prior work on disclosure in incomplete information Cournot models because we assume that firms can provide biased reports and that all firms optimally update their beliefs using all available information.² If firms bias their reports, they incur a cost of misreporting. We show that when the firms know each other's cost of misreporting, there are no linear equilibria. However, when these costs are also private information, there are linear equilibria in which the firms bias their disclosures to gain a competitive advantage in the product market. Thus, our study complements and extends the results in [Fischer and Verrecchia \(2004\)](#). In their model, only one firm has private information, and biased reporting in equilibrium requires that some firms use heuristics when adjusting their beliefs (i.e., some firms are not Bayesian). Our model differs from theirs in two important ways. First, we allow for rivalry to impact earnings management decisions (that is, more than one firm has private information) and second, because all firms optimally update their beliefs (i.e., all firms are Bayesian), we extend the literature by showing that biased reporting can occur in equilibrium in a model with fully rational firms.

Intuitively, in our model, each firm's disclosure is designed to create the impression that its production costs are lower than they actually are. Further, because each firm uses all available information efficiently and fully understands its rival's incentives to bias its report, each adjusts its beliefs about its rival's production costs upward relative to the disclosure, but still underestimates those costs in equilibrium. Consequently, each firm cuts its production below the full-information level, causing the market price to rise and each firm's product market profits to increase, in turn providing just the incentive needed for each firm to bias its disclosure.³ Our analysis indicates that these effects are smaller when firms compete in more profitable product markets or when they use reasonably similar technologies. Interestingly, while the effects are smaller in both cases, they

¹ See, for example, the book written in 2004 by Dick Martin, the former head of public relations at AT&T ([Martin 2004](#)), or the articles by [Searcy \(2005\)](#), [Blumenstein and Grant \(2004\)](#), and [McConnell et al. \(2002\)](#). While many are familiar with the most famous aspects of WorldCom's accounting fraud (i.e., capitalizing line costs and booking non-existent revenues), there appears to be no bright line between earnings management and fraud ([Mulford and Comiskey 2002](#), 41; [Ronen and Yaari, 2008](#), 25–31; [Schilit 1993](#), 1; or the survey by [Beneish 2001](#)). This is probably due, in part, to the inherent difficulties in adequately defining earnings management and distinguishing it from fraud. In WorldCom's case, its manipulation of earnings began slowly and became more egregious, culminating in actions that virtually all agree are fraud. Some of the early activities that may or may not be fraudulent include recording and releasing reserves and capitalizing internal labor costs related to line installation ([Thornburgh 2002](#)).

² The prior work using incomplete information Cournot models includes [Fried \(1984\)](#), [Shapiro \(1986\)](#), [Gal-Or \(1986, 1988\)](#), [Darrrough \(1993\)](#), [Raith \(1996\)](#), and [Vives \(2002\)](#). Also see the surveys by [Verrecchia \(2001\)](#) and [Vives \(2006\)](#). When these authors focus on disclosure, they assume that the firms' disclosures are unbiased but that the firms can determine the amount of noise in the disclosure. Thus, if the firm wishes to disclose, then it chooses not to add noise and if it wishes not to disclose, it chooses to add an infinite amount of noise.

³ As a result, the transmission mechanism that produces value to biasing reports is different in our setting than in [Fischer and Verrecchia \(2004\)](#). In their setting, the Bayesian firms recognize that their rivals employ heuristics and thus "overproduce" relative to the full-information setting. Realizing this, the Bayesian firms accommodate the increased production by reducing theirs. In our model, a firm's biased report leaves its rivals rationally believing that the reporting firm's costs are lower than they actually are, which leads the rival to believe that the reporting firm will produce more than it actually does. As a result, in a symmetric equilibrium, total output is less than the full-information level and so both firms benefit.

differ in that firms engage in more (less) misreporting in the first (second) situation. Finally, when firms have sufficiently different costs of misreporting, the firm with lower costs introduces greater bias into its reports, produces more output than it would in the full-information outcome, and earns greater product market profits. Thus, our analysis supports Armstrong's view of the competitive impact of WorldCom's fraudulent accounting and suggests that it may be worth examining similar competitive environments for similar activity.

By focusing on equilibrium incentives to bias reports, our analysis suggests new empirical implications associated with the use of different earnings management techniques. First, only some such techniques effectively bias inferences about the firm's production costs.⁴ Thus, our model predicts that the use of these techniques is positively correlated with standard measures of profitability such as ROE calculated using original (unadjusted) financial statement information but negatively correlated with these measures calculated using restated (adjusted) financial statement information, if available.⁵ In addition, if incentives to use other earnings management techniques are orthogonal to the product market incentives that are the focus of our analysis, then increases in the cost of these latter techniques (e.g., as the result of the passage of the Sarbanes-Oxley Act of 2002) should reduce the observed proportions of their use among SEC enforcement actions. Third, we show that firms with similar production technologies will be less likely to employ these types of earnings management techniques. Thus, firms whose production is governed by physical or chemical processes or firms in mature industries are less likely to engage in this type of earnings management than firms in service industries or firms that have significantly larger portfolios of products. Finally, our analysis suggests that the increased use of deferred prosecution agreements (DPAs) is likely to lead to unexpected consequences. In particular, because such agreements dramatically increase the cost of misreporting, competitors of firms operating under DPAs are likely to respond by increasing the amount of misreporting in order to gain/increase their competitive advantage in the product market.

In addition to contributing to the literature on the interaction between disclosure and product market competition, our study also highlights and extends a key insight of Fischer and Verrecchia (2000) into biased disclosures. They introduce uncertainty about the manager's objective function into a standard voluntary disclosure model (e.g., Verrecchia 1983) and show that the manager optimally introduces bias into the disclosure. Essentially, the agency problem combines with incomplete contracting to limit the market's ability to fully adjust its expectation of firm value leaving the manager with a personal benefit to offering a biased voluntary disclosure. In our model, the additional uncertainty associated with the market being unsure of the firm's reporting costs opens a similar opportunity for the firm to bias its disclosure, but does not rely on the combination of an agency problem and incomplete contracting. Thus, our model enriches the understanding of biased disclosures by showing that they may arise even if all agency problems and incomplete contracting issues are eliminated.

The literature on the interaction between disclosures and product market competition is extended and synthesized in Darrough (1993), generalized in Raith (1996), and summarized in

⁴ Examples of this type of earnings management include fraudulent or aggressive revenue recognition, aggressive cost capitalization, inclusion of operating costs in restructuring costs, inappropriately low estimates of the allowance for doubtful accounts or warranty expense, and certain types of "real" earnings management such as delaying expenditures. Examples of earnings management techniques that would not be expected to lead to biased inferences about production costs include channel stuffing, delayed write-downs of assets, and the "timely" sale of assets.

⁵ Since adjusted financial statement information is generally only available for firms that have restated earnings, this result is likely to be most easily tested by focusing on the subset of firms that have restated earnings and admitted to employing earnings management techniques that effectively bias inferences about production costs.

Vives (2006).⁶ The key difference between this literature and our model is that prior work required firms to make unbiased disclosures—firms could only alter the amount of noise in their disclosure—whereas we permit firms to bias their disclosures at a cost. This difference leads to very different predictions. For Cournot competitors with private information about production costs, Darrough (1993) and others have shown that firms prefer to precommit to disclosing their private information without adding any noise. Intuitively, adding noise results in the firm's rival choosing to produce more than it would if fully informed, which lowers price and product market profits.⁷ If the disclosure decision is made after firms learn their production costs, then because they are required to disclose truthfully, the standard unraveling story holds.⁸ Our results complement this literature by showing that when fully rational firms are permitted to bias disclosures (even at a cost), they choose to do so and that this decision is affected by and affects competition in the product market.⁹

Our analysis is also related to recent work by Sadka (2006) and Kedia and Philippon (2009). Sadka (2006) examines accounting fraud in a competitive (price-taking) model in which fraud is detectable unless the firm alters its output decisions to mimic a low-cost producer. He shows that accounting fraud lowers social welfare because the fraudulent firms produce too much output at too high a cost and the low-cost firms produce too little relative to the Pareto Efficient outcome. Kedia and Philippon (2009) examine accounting fraud in a signaling framework in which the fraudulent firm must overinvest and overhire in order to mimic the more efficient producers. They exploit this structure to suggest why the detection of accounting fraud can impact not only the firm's rivals, but can have economy-wide effects, too. Thus, while the models differ, the central idea is that fraud can be detected by examining a firm's real (as opposed to financial) decisions and that this is the transmission mechanism that links reporting activity to real effects. Our analysis complements this approach by showing that there is an additional linkage by which firms can influence their competitive position in the product market by introducing bias into their financial reports.

Section II contains a description of our model of disclosure and product market competition. In Section III, we discuss equilibrium in restricted versions of our model. In Section IV, we focus on symmetric equilibria and analyze asymmetric equilibria in Section V. We conclude in Section VI.

II. THE MODEL AND EQUILIBRIUM

In this section, we develop a model designed to provide insight into how earnings management affects product market competition and how competition affects earnings management decisions. To address these questions, we need to fully capture the idea that each firm understands that its rival will try to extract an information advantage from the firm's financial reports while

⁶ There is also an important literature on product market competition as a source of the cost of voluntary disclosures. This literature frequently focuses on the effects on a rival's entry decision from an incumbent firm's voluntary disclosure, thus endogenizing the cost of voluntary disclosure. The foundational studies in this literature include Darrough and Stoughton (1990), Wagenhofer (1990), and Feltham and Xie (1992).

⁷ In a recent study, Sadka (2004) explores how disclosure of cost information, especially by the low-cost producer, can affect a firm's competitive advantage in a product market and exploits this model to show that the key results in Darrough (1993) are reinforced by the existence of his endogenized costs of disclosure.

⁸ See Christensen and Feltham (2002) for a nice summary of this literature. Interestingly, Arya et al. (2010) show that if firms compete in multiple markets, then the unraveling result may fail. In particular, they show that there can be a partial pooling equilibrium in which firm types that have high costs in one market and low costs in the second pool with firm types with low costs in the first and high costs in the second.

⁹ The issue of whether the firms precommit to disclose does not arise substantively in our model because firms can select a disclosure that is independent of their private information. Thus, even if firms precommit to disclose, they have an available strategy that allows them to reveal none of their private information.

simultaneously understanding that its rival realizes that the firm is trying to do the same thing—extract an information advantage from the rival's financial reports. Thus, a key feature is that not only is there an information extraction problem, but there is also an important component of rivalry in determining how each firm manages its earnings (in addition to the rivalry associated with the firms' competition in the product market).

To adequately capture these forces, both firms must be privately informed about their own costs and these costs must be correlated. Both firms having private information is required in order to analyze the competitive component of their earnings management decisions. If there is only one privately informed firm, then it is the only firm that can engage in earnings management designed to affect competition in the product market and so competition to manage earnings would be eliminated by assumption. The reason the firms' costs need to be correlated is somewhat more subtle, but can be most clearly seen by considering the impact of assuming the opposite—that their costs are not correlated. If this is case, then a firm's private information is not helpful in estimating its rival's costs, and thus the firm's financial reports *only* provide the rival with information about the firm's costs of production. Consequently, the firm's report can only impact competition in the product market—there is no competitive effect in the firms' earnings management decisions. However, when the firms' costs are correlated, the information one firm extracts about its rival's costs not only informs it about those costs, but also provides additional information about the rival's ability to extract information from the firm's own report.¹⁰

To address our research questions, we examine a two-stage game that captures the interactions between firm disclosures, earnings management decisions, and competitive pressures in the product market. In the first stage, each of two firms chooses a disclosure without knowing its rival's choice and incurs a disclosure cost. Each firm makes this disclosure knowing both its own disclosure and production costs. In the second stage, the firms observe both disclosures from the first stage and compete in the product market by choosing an amount of the homogeneous product to offer for sale without observing the output choice of its rival. We simplify the analysis by assuming that each firm has constant marginal costs of production and fixed costs are zero. Together, these imply that the firm's average costs of production equal its marginal costs.

In the disclosure stage, each firm chooses a disclosure that we interpret as a disclosure about its average cost of production. Our objective is to capture the idea that a firm's financial statements (e.g., an income statement) can be used to infer the firm's reported marginal/average costs. Further, since firms can make reporting decisions that either enhance or diminish reported earnings (both within the discretion afforded by GAAP or through fraud), we do not require truthful disclosure. Instead, we assume that a firm that does not disclose truthfully incurs a disclosure cost $h_i(s_i, c_i)$, $i = 1, 2$, where s_i is firm i 's disclosure and c_i is its cost of production. To keep the analysis tractable, we assume that $h_i(s_i, c_i) = k_i(s_i - c_i) + (1/2)\varepsilon_i(s_i - c_i)^2$, with $\varepsilon_i > 0$.¹¹ Notice that with this specification, firms that disclose truthfully incur no disclosure costs, but firms that do not incur two types of costs. The first type (represented by the second term) imposes a quadratic cost of misreporting c_i —if the firm misreports ($s_i \neq c_i$), it incurs a cost that is proportional to the

¹⁰ As an example, consider the case when each firms' costs of production are made up of two components, a common and an idiosyncratic component. If the firms' costs are not correlated, then the common component must be common knowledge and all each firm needs to do is extract its rival's idiosyncratic component from its rival's financial report. However, when the common component is not known with certainty, then the firm itself will be unsure of the split between the common and its idiosyncratic components and will use its *rival's* financial report to help it understand its own split. This will, in turn, impact its inference about its rival's production costs and the rival will need to factor this effect in when determining whether (or how much) to manage its earnings.

¹¹ Throughout, we assume that these costs are not prohibitively large.

squared difference between its disclosure and its actual marginal cost of production.¹² As a result, it is symmetric in deviations from disclosing truthfully. The second type of disclosure cost (represented by the first term) is not symmetric and depends on the sign of k_i . Intuitively, if $k_i > 0$, then the firm's disclosure costs increase when its disclosure exceeds its actual marginal cost of production and may represent an added disadvantage from the market inferring that it is less competitive. Similarly, if $k_i < 0$, then the firm's disclosure costs increase when its disclosure is smaller than its actual marginal costs and may represent an added disadvantage associated with a (perceived) weakened position in bargaining with employees or in dealing with regulators (Watts and Zimmerman 1986, 1990).

In the production stage of the game, the firms observe the first-stage disclosures (s_1, s_2), draw inferences from these disclosures optimally and compete in the product market. We model the product market using a fairly standard incomplete information, Cournot duopoly model where firms know their own costs of production but do not know their rival's.¹³ More specifically, we assume that market demand for the homogeneous product sold by the two firms is $P = a - q_1 - q_2$ and units of output are normalized so that the slope coefficient is 1. All information about market demand is common knowledge.

An important component of our model is the information structure. We assume that firm i knows its own disclosure costs (k_i) and its costs of production (c_i) but not its rival's disclosure costs (k_j) or its rival's costs of production (c_j). All other parameters are common knowledge. Thus, each firm has two pieces of private information, k_i and c_i , and does not know k_j and c_j .¹⁴ We assume that each firm's priors are that its rival's disclosure costs are independent and normally distributed and that its rival's marginal costs of production are also normally distributed. A key feature of our model is that the covariance between the two firms' marginal costs is non-negative. Thus, each firm can learn about its rival's marginal costs when it learns its own marginal costs. More formally, k_1 and k_2 are independent, normally distributed random variables with zero means and variances $\sigma_{k_1 k_1}, \sigma_{k_2 k_2}$. Further, $c_i \sim N(E[c_i], \sigma_{ii})$ for $i = 1, 2$ and $\text{Cov}[c_1, c_2] \equiv \sigma_{12} \geq 0$.

A key difference between our model and most others in the literature is that each firm has two sources of private information: its disclosure costs and its production costs.¹⁵ Thus, firm i 's disclosure in the first stage is likely to depend on both components of its private information and, therefore, may provide its rival with information about c_i . If so, then the disclosure will affect how the firms compete in the product market.

As is standard, we focus on linear equilibria. In the first stage of the game, each firm knows its own disclosure and production costs. That is, firm i 's first period information set is $y_i^1 = (c_i, k_i)$, so we conjecture that each firm uses a strategy that is linear in the elements of its first stage information set. In the second stage, each firm has observed the disclosures made in the first stage and, as a result, firm i 's information set is $y_i = (c_i, s_i, s_j)$. While firm i 's own disclosure does not provide it with additional information, we include s_i because its rival uses s_i to infer c_i ; we do

¹² Quadratic cost functions have become relatively common in the disclosure literature because they support linear equilibria in Cournot-like models. See, for example, Crawford and Sobel (1982), Fischer and Stocken (2001), and Chakraborty and Harbaugh (2007) who employ a quadratic cost function in their models of cheap talk, as well as the models in Stocken and Verrecchia (2004), Fischer and Stocken (2004), and Guttman et al. (2006).

¹³ Prior work using a Cournot model with incomplete information about costs include Fried (1984), Shapiro (1986), Gal-Or (1986, 1988), Darrough (1993), and Vives (2002). Also, see the survey by Verrecchia (2001).

¹⁴ Formally, we are assuming that each firm's type is two-dimensional, $t_i = (k_i, c_i) \in \mathcal{R}^2$.

¹⁵ The main exceptions are Fischer and Verrecchia (2000) and studies that build on their model such as Har et al. (2009). In these models, incomplete contracting limits the market's ability to understand how managerial compensation is linked to stock price. Since the manager does know how his/her compensation is linked to stock price and has private information about the firm's future performance, the manager has two sources of private information in Fischer and Verrecchia-type models, although the sources differ from those studied here.

not include k_i because its rival does not observe it and it is independent of all other unknowns. Thus, firm i anticipates that q_j will depend on s_i and therefore conditions its own output choice on s_i . Neither firm's output choice depends on k_i because neither uses its own disclosure to infer its own private information. Consequently, we conjecture that in equilibrium:

$$\begin{aligned} s_1 &= D_0 + D_1 c_1 + D_2 k_1 \\ s_2 &= F_0 + F_1 c_2 + F_2 k_2 \\ q_1 &= N_0 + N_1 c_1 + N_2 s_1 + N_3 s_2 \\ q_2 &= M_0 + M_1 c_2 + M_2 s_1 + M_3 s_2. \end{aligned} \quad (\text{C1})$$

To solve for a perfect Bayes equilibrium of the game, we begin by analyzing the second-stage game in which firms compete in the product market given their prior disclosures and their inferences about their rival's private information. Given our normality assumptions and our focus on linear equilibria, we make the additional conjecture that:¹⁶

$$\begin{aligned} E[c_1|y_2] &= \alpha_0 + \alpha_1 c_2 + \alpha_2 s_1 \\ E[c_2|y_1] &= \beta_0 + \beta_1 c_1 + \beta_2 s_2. \end{aligned} \quad (\text{C2})$$

Given these conjectures, in the second stage, firm i solves:

$$\max_{q_i} E[(a - Q)q_i - c_i q_i | y_i] \equiv \max_{q_i} a q_i - q_i^2 - E[q_j | y_i] q_i - c_i q_i. \quad (1)$$

Note that the first-stage disclosure costs are ignored because, in the second stage, they are a sunk cost and thus do not affect the optimal output decision. The first-order condition for this maximization problem is $0 = a - 2q_i - E[q_j | y_i] - c_i$, which forms the basis for Proposition 1:¹⁷

Proposition 1: If (C1) and (C2) hold, then there exists a linear equilibrium (q_1^*, q_2^*) to the production game with:

$$\begin{aligned} q_1^* &= N_0 + N_1 c_1 + N_2 s_1 + N_3 s_2 \\ q_2^* &= M_0 + M_1 c_2 + M_2 s_1 + M_3 s_2, \end{aligned}$$

where:

$$\begin{aligned} N_0 &= (1/3) \left(a - \frac{(2 - \beta_1)\alpha_0}{4 - \alpha_1\beta_1} + \frac{2(2 - \alpha_1)\beta_0}{4 - \alpha_1\beta_1} \right) & M_0 &= (1/3) \left(a - \frac{(2 - \alpha_1)\beta_0}{4 - \alpha_1\beta_1} + \frac{2(2 - \beta_1)\alpha_0}{4 - \alpha_1\beta_1} \right) \\ N_1 &= -\frac{2 - \beta_1}{4 - \alpha_1\beta_1} & M_1 &= -\frac{2 - \alpha_1}{4 - \alpha_1\beta_1} \\ N_2 &= -(1/3)\alpha_2 \left(\frac{2 - \beta_1}{4 - \alpha_1\beta_1} \right) & M_2 &= (2/3)\alpha_2 \left(\frac{2 - \beta_1}{4 - \alpha_1\beta_1} \right) \end{aligned}$$

¹⁶ In a linear equilibrium, we will have to compute all of the conjectured coefficients in Equations (C1) and (C2).

¹⁷ The second-order condition is satisfied since the coefficient on q_i is negative.

$$N_3 = (2/3)\beta_2 \left(\frac{2 - \alpha_1}{4 - \alpha_1\beta_1} \right) \quad M_3 = - (1/3)\beta_2 \left(\frac{2 - \alpha_1}{4 - \alpha_1\beta_1} \right).$$

There are two important features of this linear equilibrium that we should highlight. First, each firm's equilibrium production strategy depends on its rival's disclosure, its actual production costs and its own disclosure. The (potentially) unintuitive feature is that the firm's production strategy depends on its own disclosure despite the fact that the firm knows its own cost of production and uses it rather than its own disclosure to estimate its rival's marginal cost of production. As suggested above, the reason for this dependence is that firm i knows that its rival is using i 's disclosure to make inferences about i 's production costs (see Equations (C2)) and thus i can infer that its rival's production strategy will depend on s_i . Since firm i 's production strategy depends on its inference about firm j 's production decision that firm i knows depends on s_i , firm i 's production strategy "indirectly" depends on its own disclosure because of the information its rival can extract from that disclosure. Second, the parameters describing the equilibrium production strategies (the M 's and N 's) depend on the coefficients in the conditional expectations described by (C2). Intuitively, both firms use all of their private information and their public disclosures from the disclosure stage to infer as much as they possibly can about their rival's production costs.

Proposition 1 can also be used to derive each firm's equilibrium expected second stage profits. Substituting q_i^* into Equation (1) shows that, as is usual in Cournot games, firm i 's equilibrium expected second stage profits are:

$$E[\pi_i^2 | y_i] = (a - c_i - q_i^* - E[q_j^* | y_i])q_i^* = (1/2)(q_i^*)^2.$$

It will also be useful to have simplified expressions for $E[q_j^* | y_i]$. This is most readily obtained from Proposition 1 by taking expectations:

$$E[q_2^* | y_1] = M_0 + M_1 E[c_2 | y_1] + M_2 s_1 + M_3 s_2$$

$$E[q_1^* | y_2] = N_0 + N_1 E[c_1 | y_2] + N_2 s_1 + N_3 s_2.$$

Substituting for $E[c_i | y_j]$ from (C2) shows that each equation has the form implied by (C1):

$$E[q_2^* | y_1] = A_0 + A_1 c_1 + A_2 s_1 + A_3 s_2 \quad (2)$$

$$E[q_1^* | y_2] = B_0 + B_1 c_2 + B_2 s_1 + B_3 s_2. \quad (3)$$

Folding back to the disclosure stage, each firm chooses a disclosure, s_i , which we interpret as a disclosure about the firm's average (equivalently, in our model, marginal) cost of production. Recall that our interpretation is that the firm's income statement can be used to infer the firm's reported average costs. Given our distributional and information assumptions, in the first stage of the game, firm i chooses s_i to maximize its expected profits in the two-stage game overall:¹⁸

¹⁸ The maximand also highlights the importance and implications of our assuming quadratic costs of disclosure. In particular, if $\varepsilon_i = 0$ so that disclosure costs are linear, then we will only find corner solutions to the firm's maximization problem. If, on the other hand, $\varepsilon_i \neq 0$, then disclosure costs are quadratic, the firm's maximization problem has an interior solution, and we can identify the linear equilibrium we seek. Further, because k_i is the coefficient on the linear term of the disclosure costs, its value only affects the intercept of the firm's reaction function and, thus, the particular value it takes on does not impact our ability to find interior solutions to the firm's maximization problem.

$$\max_{s_i} (1/2)E[(q_i^*)^2 | y_i^1] - k_i(s_i - c_i) - \varepsilon_i(s_i - c_i)^2.$$

Substituting equilibrium outputs from Proposition 1, and maximizing with respect to s_1 (s_2) yields:

$$s_1 = \left[\frac{1}{\varepsilon_1 - A_2^2} \right] (-A_2(a - A_0) + (\varepsilon_1 + A_2(1 + A_1))c_1 - k_1 - A_2A_3E[s_2 | c_1, k_1]) \tag{4}$$

$$s_2 = \left[\frac{1}{\varepsilon_2 - B_3^2} \right] (-B_3(a - B_0) + (\varepsilon_2 + B_3(1 + B_1))c_2 - k_2 - B_2B_3E[s_1 | c_2, k_2]). \tag{5}$$

Since k_1 and k_2 are not correlated with each other or the firms' marginal costs of production, $E[s_j | k_i, c_i] = E[s_j | c_i]$. Equations (4) and (5) suggest that s_i is linear in c_i, k_i , as long as the conditional expectations $E[s_j | c_i]$ are linear in those variables, too. Proposition 2 provides conditions under which the s_i^* s are, in fact, linear.

Proposition 2: In every linear equilibrium, (q_i^*, q_2^*) are defined as in Proposition 1 and (s_1^*, s_2^*) satisfy:

$$s_1^* = D_0 + D_1c_1 + D_2k_1$$

$$s_2^* = F_0 + F_1c_2 + F_2k_2,$$

where:

$$E[c_2 | c_1] = \mu_0 + \mu_1c_1$$

$$E[c_1 | c_2] = \delta_0 + \delta_1c_2$$

$$D_0 = \frac{1}{\varepsilon_1 - A_2^2} [-A_2(a - A_0 + A_3F_0 + A_3F_1\mu_0)] \quad F_0 = \frac{1}{\varepsilon_2 - B_3^2} [-B_3(a - B_0 + B_2D_0 - B_2D_1\delta_0)]$$

$$D_1 = \frac{1}{\varepsilon_1 - A_2^2} [A_2(1 + A_1) - A_2A_3F_1\mu_1 + \varepsilon_1] \quad F_1 = \frac{1}{\varepsilon_2 - B_3^2} [B_3(1 + B_1) - B_2B_3D_1\delta_1 + \varepsilon_2]$$

$$D_2 = -\left(\frac{1}{\varepsilon_1 - A_2^2} \right) \quad F_2 = -\left(\frac{1}{\varepsilon_2 - B_3^2} \right).$$

We also observe that in any linear equilibrium as described in Proposition 2:

$$E[c_2 | c_1, s_2] = E[c_2] + \left(\frac{\sigma_{12}\sigma_{k_2k_2}F_2^2}{\sigma_{11}(\sigma_{22}F_1^2 + \sigma_{k_2k_2}F_2^2) - \sigma_{12}^2F_1^2} \right) (c_1 - E[c_1])$$

$$+ \left(\frac{\sigma_{11}\sigma_{22}F_1 - \sigma_{12}^2F_1}{\sigma_{11}(\sigma_{22}F_1^2 + \sigma_{k_2k_2}F_2^2) - \sigma_{12}^2F_1^2} \right) (s_2 - F_0 - F_1E[c_2])$$

$$E[c_1 | c_2, s_1] = E[c_1] + \left(\frac{\sigma_{12}\sigma_{k_1k_1}D_2^2}{(\sigma_{11}D_1^2 + \sigma_{k_1k_1}D_2^2)\sigma_{22} - \sigma_{12}^2D_1^2} \right) (c_2 - E[c_2])$$

$$+ \left(\frac{\sigma_{11}\sigma_{22}D_1 - \sigma_{12}^2D_1}{(\sigma_{11}D_1^2 + \sigma_{k_1k_1}D_2^2)\sigma_{22} - \sigma_{12}^2D_1^2} \right) (s_1 - D_0 - D_1E[c_1]),$$

and a linear equilibrium requires that these coefficients match the α 's and β 's in Equations (C2).

Unfortunately, there is no general result on the existence of a perfect Bayes equilibrium in this type of linear-normal model.¹⁹ Further, finding a linear equilibrium in closed form for our model is very difficult because it requires solving a system of 24 nonlinear equations for the unknown coefficients. Both numerical solutions and closed-form solutions for restricted versions that eliminate some of the key forces in the model are analyzed below. However, before examining the properties of the solutions, we explain the importance of our assumption that there are two sources of private information.

The easiest way to see the importance of assuming that there are two sources of private information rather than just one is to consider the effect of assuming that both firms know the realizations of k_1 and k_2 (equivalently that $\sigma_{k_1, k_1} = \sigma_{k_2, k_2} = 0$). If so, then each firm has one source of private information: their own costs of production. As a result, any disclosure strategy that is monotone in the firm's private information can be inverted, which allows all to infer the firm's private information exactly and we are able to prove the following result:

Proposition 3: If k_1 and k_2 are common knowledge, then there are no monotone equilibria in pure strategies.

The key implication of assuming that k_1 and k_2 are common knowledge is that neither firm can employ a monotone disclosure strategy without revealing its actual production costs. That is, if the conjectured disclosures are monotone in the firm's private information, even if biased, then they allow each firm to infer the other's costs and thus be fully informed when they compete in the product market. As a result, if a firm deviates from the conjectured disclosure strategy and biases its reported costs downward, then the rival would infer that the deviating firm's costs are lower and accommodate the firm by producing less. This allows the deviating firm to produce more and shift product market profits from its rival to itself.

In the following section, we examine restricted versions of our model that allow for closed-form solutions at the cost of eliminating key components of the information extraction problem and how rivalry impacts the firms' decisions to bias their reported earnings. In Section IV, we examine numerical solutions of the full model and highlight both of these features.

III. RESTRICTED VERSIONS OF THE MODEL

In this section, we examine two special cases of the model described above that simplify the computation of a linear equilibrium at the cost of eliminating important forces in the model.

We begin by restricting the analysis to the case when the firms' private information is uncorrelated. As we noted in the previous section, this restriction eliminates a key force in our model—the impact of learning about what the rival can learn from the firm's own financial reports. This assumption, that $\sigma_{12} = 0$, implies that, in Proposition 2, α_1 and β_1 are both zero. While it is true that eliminating this dimension of each firm learning about the information its rival can extract from its financial reports does simplify the system of equations mentioned above, it does not simplify them enough to offer useful closed-form solutions.²⁰

To obtain a manageable linear equilibrium, we introduce a second restriction: only one firm has private information. The cost of this restriction is that it eliminates the impact of rivalry on the

¹⁹ With minor modifications to our distributional assumptions, however, the existence of a trembling hand perfect Nash equilibrium ensures that there is a perfect Bayes equilibrium (see Fudenberg and Tirole 1993). In particular, if each firm's private information is drawn from a finite set (so that the set of types in our game is finite), standard existence theorems ensure that there is a trembling hand perfect Nash equilibrium and therefore a perfect Bayes equilibrium in the modified game.

²⁰ Algebraic manipulation, available from the authors, produces a quadratic equation with one real root. Unfortunately, the root is a very complex function of the exogenous variables and requires that we again revert to numerical solutions.

earnings management decision as well as a key component of each firm's inference problem. Without loss of generality, assume that c_2 is common knowledge and since firm 2's costs are known, set $k_2 \equiv 0$.

Corollary: If c_2 is common knowledge, $k_2 \equiv 0$ and $\sigma_{12} = 0$, then there is a linear equilibrium $\{(s_1^*, q_1^*(s_1, s_2)), (s_2^*, q_2^*(s_1, s_2))\}$ defined by:

$$q_1^* = (1/6)(2(a + \beta_0) - 3c_1 - s_1 + 2\beta_2 s_2)$$

$$q_2^* = (1/6)(2(a - (1/2)\beta_0) - 3c_2 + 2s_1 - \beta_2 s_2)$$

$$s_1^* = \left(\frac{1}{9\varepsilon_1 - 1} \right) [2a - (1/2)\beta_0 + (3 + \varepsilon_1)c_1 + (1/2)(3 + \beta_2)c_2 - 9k_1]$$

$$s_2^* = c_2,$$

with:

$$E[c_1 | c_2, s_1] = \beta_0 + \beta_2 s_1.$$

$$E[c_2 | c_1, s_2] = c_2$$

$$\beta_0 = \left(1 - \frac{(3 + \varepsilon_1)\beta_2}{9\varepsilon_1 - 1} \right) E[c_1]$$

$$\beta_2 = \left(\frac{1}{9\varepsilon_1 - 1} \right)^2 \left[\frac{(9\varepsilon_1 - 1)(3 + \varepsilon_1)\sigma_{11}}{(3 + \varepsilon_1)^2\sigma_{11} + 81\sigma_{kk}} \right].$$

Despite the significant restrictions that eliminate many key forces, the equilibrium described in the Corollary does have a couple of interesting features. First, because firm 2's costs are common knowledge, only firm 1 has the opportunity to impact product market competition by its disclosure policy—and it chooses to do so in equilibrium. The reason it chooses to do so is that firm 2 cannot “look through” firm 1's disclosure and correctly infer firm 1's costs of production. The two sources of private information mean that firm 2 optimally attributes part of the difference between firm 1's reported cost (s_1^*) and its expected cost ($E[c_1]$) to the realized value of k_1 and the rest to firm 1's cost of production (c_1). Thus, firm 1 has an incentive to underreport its costs (when $k_1 = 0$) and, despite firm 2 optimally updating its expectation of firm 1's costs, firm 2 is left with the belief that firm 1's costs are lower than they actually are. Firm 2, therefore, optimally responds to its belief about firm 1's costs by producing fewer units than it would if it knew firm 1's costs. Firm 1 anticipates this reaction to its disclosure and produces more than it would had firm 2 known firm 1's costs. The end result is that profits are shifted from firm 2 to firm 1 providing the motivation for firm 1 to bias its disclosure. Put differently, competition in the product market induces firm 1 to bias its report and the biased report alters the competitive outcome in the product market.

A disadvantage of this restricted model is that there are few interesting comparative statics. As one would expect, as firm 1's cost of providing a misleading disclosure increases, it offers a less biased report and earns smaller profits. For essentially the same reasons, if the size of the product market is smaller (α declines), then firm 1 offers a less biased report and earns smaller profits. In the first case, the cost of biasing its disclosure increases and so it does less. In the latter case, the benefits of biasing its disclosure decrease and so it does less.

Interestingly, despite the limitations of this version of the model, it still contributes to the existing literature on biased reporting. For example, Fischer and Verrecchia (2004) study transparent disclosure bias in a Cournot oligopoly model with firms that employ heuristics to interpret new information. In their model, some firms over-react to information and, in equilibrium, the informed firm biases its disclosure. In essence, firms that employ heuristics “believe” their disclosure/interpretation and produce more output than they would if they were Bayesian. Bayesian firms realize this and accommodate the added output, thereby producing a benefit to the heuristic firms. Our restricted model complements Fischer and Verrecchia’s (2004) analysis by showing that biased reporting arises even when every firm optimally employs all available information (every firm is Bayesian) but still produces a similar shifting of product market profits. In contrast to Fischer and Verrecchia (2004), the bias is not fully transparent and so our analysis suggests that fully transparent biased reporting may require the non-optimal use of available information (heuristics).

Our model also complements Fischer and Verrecchia’s (2000) analysis of reporting bias. In their model, a manager is permitted to offer biased earnings reports. They show that, when investors are uncertain about how the manager’s compensation depends on stock price, in equilibrium, the manager offers a biased voluntary disclosure that is not transparent. In their model, the market’s uncertainty about the manager’s payoff is required for equilibrium to exhibit biased reports. Our model complements their analysis by showing that competition in the product market can substitute for agency problems combined with incomplete contracting as an explanation for biased reporting.

Our results for the restricted model differ markedly from those reported in the next section when both key features of our model—that both firms face an information-extraction problem and that there is an important component of rivalry in determining how each firm manages its earnings (in addition to the rivalry associated with the firms’ competition in the product market)—are present. In the full model, both firms bias their reports and this allows both to earn greater profits than they would in the full-information environment. Further, the restrictions do not allow us to explore how earnings management is affected by how much information a firm can infer about its rival or how asymmetries in the costs of misleading disclosures impacts equilibrium outcomes.

IV. SYMMETRIC EQUILIBRIA

In this section, we focus on symmetric equilibria, and in the following section, we explore the nature of asymmetric equilibria. In a symmetric equilibrium, both firms employ the same strategies (the same map from their private information to their actions). Thus, equilibrium disclosures are determined by the same function of the firm’s private information, and equilibrium production decisions are determined by the same function of each firm’s information set in the second stage. That is, symmetry requires that $D_i = F_i$ and $\alpha_i = \beta_i$ for $i = 1, 2, 3$; $N_i = M_i$ for $i = 1, 2, 3, 4$ and $\mu_i = \delta_i$ for $i = 1, 2$. Further, we must assume that both firms are in the same “competitive position:” k_1 and k_2 must be drawn from the same distribution, c_1 and c_2 must be drawn from the same distribution and the firms must incur the same disclosure costs, $\varepsilon_1 = \varepsilon_2 \equiv \varepsilon$. Finally, without loss of generality, we assume that all of the normally distributed random variables are standard normal with zero means and variances equal to 1. Given this structure, we have:

Proposition 4: If ε is not too small, then there is a symmetric linear perfect Bayes equilibrium in pure strategies.

Intuitively, if the cost of misreporting is sufficiently small, there are no linear equilibria because the incentive to misreport is too great and cannot depend linearly on the firm’s private information. However, if the cost of misreporting is larger, then there is a linear perfect Bayes equilibrium in which each firm provides a disclosure. The disclosure allows the rival to update its

beliefs about the disclosing firm's production costs but does *not* allow it to infer exactly what those costs are (i.e., the biased reports are not transparent). The update does, however, affect how the rival competes with the disclosing firm in the product market.

To better understand the properties of the disclosure and its effects on product market competition, we will generally do numerical comparative static analysis because of the complexity of the equations defining the symmetric equilibrium. However, comparative static results on the cost of misreporting can be done analytically. In particular, as the cost of misreporting increases, the amount of misreporting declines, each firm's estimate of its rival's cost of production becomes more accurate, and each firm's output approaches the output it would make in a full-information environment.²¹

Intuitively, this comparative static tells us that, as the cost of misreporting gets large, equilibrium in the product market converges to the complete information solution. The reason is that, as the cost of misreporting gets large, the firms do less which makes their disclosures more informative. Thus, the uncertainty about the rival's cost dissipates and competition in the product market approaches the full-information outcome. Interestingly, this result does not require that firms precommit to a disclosure or be required to disclose truthfully. Instead, as the cost of misreporting rises, firm behavior converges to the full-information solution where each truthfully discloses its private information about its production costs.

To clarify how equilibrium outcomes vary with the cost of misreporting, the correlation between the firm's costs of production and the size of the product market, we turn to numerical comparative static analyses. Since $h_i(s_i, c_i) = k_i(s_i - c_i) + (1/2)\varepsilon_i(s_i - c_i)^2$, a positive (negative) k_i produces marginal incentives for the firm to report $s_i < c_i$ ($s_i > c_i$). Thus, we do all numerical analyses assuming that the realized values of k_1 and k_2 are zero. We begin by analyzing the equilibrium described above in more detail and the effects of an increase in the cost of misreporting.

Result 1: In equilibrium, each firm's reported cost of production is smaller than its actual cost of production, each firm's output is smaller than the full-information quantity and each firm's estimate of its rival's costs is smaller than its rival's actual cost of production.²²

This result tells us that firms bias their reported costs downward in an attempt to create the impression that their costs are lower than they actually are.²³ If successful, their rival will optimally reduce the amount it sells in the product market, causing the price to be higher and resulting in greater profits for the misreporting firm. Each firm, in equilibrium, is successful because neither can perfectly extract its rival's production costs from reported costs. Each understands the equilibrium and adjusts its expectation of the rival's cost taking into account the rival's incentive to report lower costs but, despite this, the adjustment is only partial. We emphasize that neither firm is "fooled." Each uses all available information (its private information about its own costs and the

²¹ See the Appendix for a proof of these assertions.

²² Further, combining Result 1 with our comparative static results on changes in ε , when the cost of misreporting increases, all differences shrink. Reported costs converge to actual costs, output choices converge to the full-information quantities, and each firm's estimate of its rival's costs converge to its rival's actual costs.

²³ We should clarify that we are not using biased in the classical statistical sense but rather, to use Fischer and Verrecchia's (2000) term, in the "realized" sense. This distinction is standard in the biased disclosure literature and is important to understanding our results because both firms are Bayesian, which implies that there is no bias in the classical statistical sense. There is, however, bias in the "realized" sense that can be seen as follows. Since s_i is linear in c_i and k_i , it is normally distributed and so, after suppressing conditioning on c_j , we can write $E[c_i | s_i] = E[c_i] + \kappa(s_i - E[s_i])$. Recalling that $k = 0$, substituting for s_i and $E[s_i]$ and rearranging, we obtain $\lambda c_i - E[c_i | s_i] = -(1 - \lambda)E[c_i]$. Evaluating at $E[c_i] = 0$ and noting that $0 < \lambda < 1$, we have that $c_i > E[c_i | s_i]$. That is, each firm's estimate of its rival's costs is smaller than its rival's actual cost of production.

disclosures) to make the best possible estimate of its rival's production costs. Each underestimates its rival's costs because there are two reasons why they can be small—either the costs of production actually are small; or the costs of misreporting are small, making it less expensive to misreport—and the firm cannot completely sort out the two effects.²⁴

These results differ markedly from the results for Cournot models in the prior literature (Darrough 1993; Raith 1996). Darrough (1993) proves that, in a Cournot model, if the firm's disclosure is required to be a noisy but unbiased reflection of the firm's private information about its cost of production, then in equilibrium, both firms would precommit to minimize the noise in the disclosure.²⁵ That is, they report their private information without bias. Other models permit firms to choose whether to disclose after learning their production costs but require truthful disclosures. This literature, summarized in Christensen and Feltham (2002), shows that the standard unraveling result applies—in equilibrium, every firm-type discloses because if more than one type is pooled together, then the type with the lowest production costs can increase profits by disclosing its costs and inducing its rivals to reduce the quantities they offer for sale. In our model, firms are not required to disclose truthfully, but if they report with a bias, they incur a cost associated with misreporting. Our analysis shows that when firms have the option to bias their disclosure (even at a cost), they do so and that the effects are only partially accounted for by the rival.

Result 1 also highlights the importance of rivalry in the earnings management decision.²⁶ In particular, even though both firms are fully rational and optimally use all available information, biased reporting occurs in equilibrium and leads to greater industry profits. This differs from both the results in Fischer and Verrecchia (2004) and our restricted model. In particular, in Fischer and Verrecchia (2004), profits are shifted from firms that use Bayes' Rule to those using a particular heuristic and leads to lower overall industry profits. In our restricted model, profits are shifted from the firm without private information to the firm with private information (via the latter's biased disclosure) and again leads to lower industry profits. In contrast to the aforementioned models without rivalry in the disclosure stage, when there is rivalry, both firms earn greater profits than the full-information outcome because both reduce output after optimally using the rival's disclosure to estimate their rival's cost of production. The impact on firm profits is described in the following result:

Result 2: In equilibrium, misreporting allows both firms to earn greater profits in the product market than they would if each had complete information about its rival's cost of production. Further, the profits the firms earn in the product market decline as the cost of misreporting increases.

Intuitively, the type of earnings management we examine allows each firm to bias its disclosure in order to affect its rival's inference about its production costs. Result 1 indicates that the

²⁴ The direction of the preferred bias (to report production costs as being smaller than they actually are) is the result of assuming that the firms are Cournot competitors. Had we assumed that the firms sold heterogeneous products and were Bertrand competitors, the direction of bias would be reversed. Formally, the reason for this difference is that quantities are strategic substitutes whereas prices are strategic complements. Intuitively, the reason is that under Bertrand competition, if firm i reports higher costs of production, it anticipates that its rival will increase its price, allowing i to increase its price thereby increasing i 's profits. The higher price increases firm profits because competition has driven the equilibrium prices below their monopoly levels.

²⁵ Formally, if the firm's private information is ψ_i , then it is required to disclose $\hat{\psi}_i = \psi_i + v_i$ where v_i is a normally distributed random variable with mean 0 and variance chosen by the disclosing firm. If the firm wishes to disclose its private information, then it selects a variance of zero and if it wishes not to disclose, it selects a variance of infinity. In neither case can the disclosing firm intentionally bias its disclosure.

²⁶ Recall that rivalry requires two assumptions: (1) that at least two firms have private information, and (2) that their information is correlated. Thus, the impact of rivalry in our model is seen by contrasting equilibrium outcomes in the restricted model (Corollary) and in our full model.

firms choose to misreport costs to create the impression that they are lower than they actually are. As a result, the rival infers that the firm will produce more than it actually does and responds by reducing the quantity it produces. Consequently, earnings management results in both firms selling less than they would, had they known their rival's costs, but the associated price increase (from selling less) results in each firm earning greater profits than it would with complete information about its rival's costs. Further, as the cost of misreporting rises, the magnitude of the bias in the firms' reports declines. Since both firms' profits in the product market are increasing in the amount of earnings management, increases in the cost of misreporting lower the equilibrium amount of earnings management and therefore lower the profits each firm earns in the product market. Further, if the costs of misreporting are nonpecuniary or are incurred by management rather than the firm, Result 2 implies that earnings management actually increases the liquidation value of the firm.

The clearest empirical implications follow from associating changes in the cost of misreporting with changes in reporting regulations. For example, Section 302 of the Sarbanes-Oxley Act of 2002 (SOX) requires, among other things, that CEOs and CFOs (or persons performing equivalent functions) personally certify in each quarterly and annual report, including transition reports, that:

he or she has reviewed the report; based on his or her knowledge, the report does not contain any untrue statement of a material fact or omit to state a material fact necessary in order to make the statements made, in light of the circumstances under which such statements were made, not misleading with respect to the period covered by the report; based on his or her knowledge, the financial statements, and other financial information included in the report, fairly present in all material respects the financial condition, results of operations and cash flows of the issuer as of, and for, the periods presented in the report.²⁷

Such certification increases the costs of misreporting and would be represented by an increase in ε in our model. Thus, the results on increases in ε and Result 1 combine to suggest the intuitive result that the impact of Section 302 is to reduce the amount of misreporting and the surprising results that: (1) each firm's estimate of its rival's costs increases and becomes more accurate, and (2) each firm produces additional output. However, to the extent that misreporting of the type we consider is important to the economy, our analysis suggests that Section 302 of SOX likely expanded gross domestic product but reduced taxable profits and tax revenues.

More importantly, our analysis suggests that only certain types of misreporting are effective means of creating a competitive advantage in the product market. In particular, aggressive cost capitalization, including operating costs in restructuring costs, or selling previously written off inventory all produce financial statements that lead the firm's rival to infer that the firm's costs are lower than they actually are. Changes in certain estimates can also produce the same result. For example, a firm that reduces the allowance for doubtful accounts (to increase earnings rather than because of changes in its customers' credit-worthiness) increases reported revenue relative to operating expenses, and thus gives its rival the impression that the reporting firm's costs are lower than they actually are. Another example is reducing warranty expense estimates (without an associated change in the reliability of the product) that directly lowers reported operating expenses and misleads the firm's rival in a similar manner. Finally, certain methods of "real" earnings management such as delaying expenditures have the same effect.

There are, however, a variety of "standard" earnings management techniques that do not create a competitive advantage of the type we examine. For example, aggressive revenue recog-

²⁷ See "Certification of Disclosure in Companies' Quarterly and Annual Reports," Securities and Exchange Commission 17 CFR PARTS 228, 229, 232, 240, 249, 270 and 274 [RELEASE NOS. 33-8124, 34-46427, IC-25722; File No. S7-21-02] RIN 3235-A154, <http://www.sec.gov/rules/final/33-8124.htm>.

dition or granting lenient credit terms (or, more aggressively, channel stuffing) all produce greater earnings (assuming gross margins are positive), but do not necessarily affect a rival's ability to use the firm's financial statements to infer its costs. Similarly, delays in writing down assets, over-reserving for contingencies or "timely" selling of assets are all means of managing earnings that do not alter the rival's ability to infer costs. Thus, assuming that firms generally face similar incentives to engage in this second class of earnings management techniques, our analysis suggests that SOX will reduce the use of the first class of earnings management techniques relative to the second. As a result, our model predicts that the observed proportion of the first class of earnings management techniques among SEC enforcement actions will be smaller post-SOX.

Result 2 also offers an alternative explanation for the "contagion" effect associated with restatements studied recently by Gleason et al. (2008), Xu et al. (2006), Da Dalt and Margetis (2004), Margetis (2004), and Gonen (2003). These studies all examine how a restatement by one firm affects the stock price of its peers. They generally find that the negative effect on the restating firm's stock price is contagious in the sense that the restatement is associated with negative effects on the stock price of its peers. These studies generally focus on the likely transmission mechanism being the market's concern that the restatement by one firm increases the likelihood of a restatement by its peers (hence the name "contagion effect"). Our analysis offers a complementary transmission mechanism for a subset of the financial restatements examined: Result 2 tells us that if the restatement by one firm increases the cost of misreporting, then each firm will respond by reducing the amount of misreporting, thereby lowering the profits each earns in the product market. This complementary transmission mechanism can be examined empirically by focusing on the future operating performance of the restating firm's peers. A deterioration in this performance would be consistent with a loss of profitability in the firms' product market and would suggest that the observed contagion effect may partly reflect the market's anticipation of this future deterioration in performance.²⁸

Having analyzed the impact of earnings management on competition in the product market, we can expand our understanding of the incentives to manage earnings by examining how changes in the product market affect each firm's willingness to misreport costs.

Result 3: When firms compete in more profitable product markets, the magnitude of misreporting is greater but the bias in the rival's estimate of a firm's cost of production is smaller, which, in turn, results in a smaller gain in equilibrium product market profits relative to the full-information level of profit.

Intuitively, Result 3 shows how the competitive environment in the product market affects incentives to engage in the type of earnings management we analyze. In particular, firms that compete in more profitable product markets (markets with larger demand intercepts) bias their reported earnings more because the benefits from inducing a rival to reduce output are greater. What may be less obvious is that the induced error in the rival's expectation of the firm's cost is smaller. The reason is that the per-unit cost of misreporting is constant so that as the profitability of the product market increases, inducing firms to report smaller costs, the total cost of misreport-

²⁸ Recently, Durnev and Mangen (2009) and Kedia and Philippon (2009) have offered alternative but similar explanations for the contagion effect. Durnev and Mangen (2009) suggest a transmission mechanism that relies on prior misstatements causing inefficient investments by a firm's peers. Based on this idea, they offer empirical evidence suggesting that a restatement by one firm in the industry is associated with more inefficient investment decisions by its rivals as measured by Tobin's marginal q . Kedia and Philippon (2009) provide a signaling explanation for why fraudulent accounting can affect not only the firm's peers but also have economy-wide effects when the equilibrium is characterized by a pooling equilibrium. Intuitively, in their model, mimicking behavior by low-productivity firms requires that they overinvest and overhire and both effects are reduced following the market's recognition that there has been significant accounting fraud by some firms in the economy.

ing rises. Thus, the increase in the amount of misreporting is tempered by the increasing total costs of misreporting, which, in net, allows its rival to better estimate the firm's true cost of production. Since the estimate is better, the impact of misreporting on the rival's output choice declines and the equilibrium outcome converges to the full-information solution.

An immediate implication of Result 3 is that reported (actual) earnings are positively (negatively) correlated with the magnitude of misreporting. As a result, our analysis predicts that most measures of profitability (e.g., Return on Equity, Return on Invested Capital, Return on Sales) calculated using the firm's unadjusted (adjusted) financial statements should be positively (negatively) correlated with the use of the types of earnings management techniques we analyze. In many cases, this result may be difficult to test because adjusted financial statements are not available. However, this difficulty might be avoided for the subset of firms that voluntarily or involuntarily provide a restatement of past financial information. For these firms, unadjusted and adjusted measures of profitability are available as are the reasons for the restatement. Together, this information would allow for an empirical test of our result. Alternatively, Result 3 implies that firms in highly profitable markets should be those firms that are more often engaged in (or engage in more) misreporting than firms in less profitable markets. As a result, our analysis suggests that firms in more profitable markets are more likely to be represented in the set of firms identified by SEC enforcement actions as having engaged in the types of earnings management that result in biasing expectations about the reporting firm's costs of production.

Result 4: The more information a firm can extract about its rival's cost from knowing its own cost, the smaller is the magnitude of the misreporting, the smaller is the induced bias in the rival's estimate of the firm's cost, and the smaller is the deviation from the full-information level of output.

The amount of information a firm can extract about its rival's costs from knowing its own costs is "measured" by the covariance between the costs, σ_{12} . In particular, the greater the covariance, the greater is the reduction in the firm's remaining uncertainty about its rival's cost after observing its own costs. The reduction in this uncertainty reduces the effectiveness of misreporting by offering a biased report, and the result is that the product market equilibrium is closer to the full-information outcome than it would be, had the firms' costs been less highly correlated.

Result 4 suggests that firms with similar technologies, such as those controlled by physical or chemical processes, should be expected to be less likely to engage in misreporting, and if they do so, to do so in smaller amounts than firms whose technologies are more likely to be very different (e.g., service industries). We also expect that firms in mature industries such as the auto or steel industries are less likely to engage in (or to do relatively less) misreporting because they are likely to have more information about their rival's production costs. Similarly, firms with large portfolios of products are more likely to engage in misreporting because their rivals are likely to be less able to infer the firm's costs of producing each product. This result could be empirically tested by relating misreporting to the number of business segments in the firm.

In summary, Results 1, 2, 3, and 4 show the full effect of firms exercising the option to bias their reported costs. Results 1 and 2 show how a firm's decision to bias its disclosure impacts competition in its product market, and Results 3 and 4 show the feedback effect—how the competitive environment in the product market affects incentives to manage earnings.

V. ASYMMETRIC EQUILIBRIA

The results in the previous section provide new insights into the relation between product market competition and misreporting designed to bias a rival's inferences about the reporting firm's cost of production. The main feature that cannot be explored when the focus is on symmetric equilibria is the impact of differential costs of misreporting.

Previously, the cost of misreporting was treated as either non-random or as the expected cost of misreporting.²⁹ The advantage of interpreting it as an expected cost is that it is natural to assume that firms face different expected costs of misreporting. Not only might firms differ in the likelihood that they are examined for misreporting, but it is also possible that firms are run by managers who differ in their concern about the impact of being detected misreporting. This situation appears to apply in the AT&T-WorldCom example cited in the introduction.

To explore the effect of different costs of misreporting, we examine asymmetric equilibria. We again apply numerical techniques because of the difficulties solving the large system of nonlinear equations that describe the equilibrium. The key difference in this section is that we relax the assumption that $\varepsilon_1 = \varepsilon_2$ by assuming, without loss of generality, that $\varepsilon_2 > \varepsilon_1$. As in the prior section, all numerical analyses assume that the realized values of k_1 and k_2 are zero.

Result 5: When ε_1 and ε_2 are sufficiently different, as ε_2 rises relative to ε_1 :

- (i) the amount of misreporting by the low-cost misreporter increases while the amount of misreporting by the high-cost misreporter declines;
- (ii) the bias in the estimate of the low-cost misreporter is greater but both converge to zero as ε_2 rises;
- (iii) the low-cost misreporter produces more output than the full-information output, while the high-cost misreporter produces less; and
- (iv) the low-cost misreporter earns greater product market profits than the high-cost misreporter does and the difference increases as ε_2 increases.

Result 5 describes how differences in the costs of misreporting affect competition. In particular, the greater the difference in the costs of misreporting, the larger (smaller) is the amount done by the low-cost (high-cost) misreporter. Thus, holding the lower cost of misreporting constant, Result 5 suggests that increases in the high-cost firm's costs motivate its rival to engage in more misreporting. In fact, Result 5 says even more: If the low cost rises slower than the high cost, then the direct effect of the cost increase on the low-cost misreporter (to reduce the amount of misreporting) is overwhelmed by the indirect, competitive effect of the increase in its rival's cost of misreporting. Further, the lower cost of misreporting offers the firm a competitive advantage in the product market, which it exploits by selling more output than its rival and earning greater profits.

Result 5 also suggests some empirically testable implications. First, if firms "forced" to replace upper management in the wake of a misreporting scandal incur higher costs of misreporting, then rivals are likely to engage in more misreporting and increase production, thereby shifting profits away from the firm that changed upper level management. Second, it suggests a potential risk from using deferred prosecution agreements in misreporting cases.³⁰ Such agreements increase (potentially dramatically) the cost of misreporting, and our Result 5 suggests that such agreements will produce unwanted competitive responses from the firm's rivals. In particular, the agreements will motivate the firm's rivals to increase their level of misreporting.

VI. CONCLUSION

We examine how earnings management affects product market competition and how rivalry impacts both production decisions and disclosure (earnings management) decisions. To do so, we

²⁹ If we assume that the cost of misreporting is uncorrelated with the firm's private information, then because the firm's payoffs are linear in that cost, we could take expectations with respect to it and simply replace the random variable with its expectation in the expressions derived above.

³⁰ Examples of the use of such agreements regarding misreporting of the type we examine include the Bristol-Myers Squibb case (<http://www.usdoj.gov/usao/nj/press/files/pdf/deferredpros.pdf>); the PNC Financial case (http://www.usdoj.gov/opa/pr/2003/June/03_crm_329.htm); the Computer Associates case (<http://www.sec.gov/litigation/litreleases/lr18891.htm>); and the AOL case (http://www.usdoj.gov/opa/pr/2004/December/04_crm_790.htm).

consider an incomplete information Cournot duopoly model in which firms know their own production costs but not their rival's. In our model, fully rational firms provide a disclosure (e.g., an income statement) that its rival can use to update its beliefs about the disclosing firm's production costs prior to competing in the product market. Our model differs from those in the prior literature in that we allow firms to provide biased reports, but if they do so, they incur a cost of misreporting. We show that biased reporting is impossible in monotone equilibria when these costs are common knowledge. However, when costs are private information, we find a linear equilibrium in which both firms bias their reports even though both are fully rational and optimally use all information when estimating their rival's costs of production. Thus, our model complements and extends Fischer and Verrecchia (2004) by showing that biased reporting does not require firms to employ heuristics rather than optimally update their beliefs. Further, our model complements and extends Fischer and Verrecchia (2000) by showing that agency problems and incomplete contracting are not required for equilibrium to exhibit biased disclosures. Finally, we extend the literature on disclosure in oligopoly by allowing biased disclosure and showing that, when it is available, firms choose to bias their disclosures.³¹

Intuitively, in our model, firms have an incentive to bias their reported costs downward and, even though all firms use all available information efficiently, fully understand each other's incentives, and adjust their beliefs about their rival's costs upward, they still underestimate those costs. As a result, each cuts production relative to the full-information level and each earns greater product market profits. Interestingly, these effects are smaller in more profitable product markets even though the magnitude of misreporting increases. They are also smaller when firms use more similar production technologies. Finally, when firms have sufficiently different (expected) costs of misreporting, the bias in the low-cost misreporter's disclosure is greater than its rival's and it produces more output than the full-information quantity.

By focusing on competitive effects and fully rational firms, our analysis suggests some empirical implications. To see why, note that aggressive cost capitalization, fraudulent revenue recognition, inappropriate estimates of the allowance for doubtful accounts, or warranty expense are all examples of (one class of) earnings management techniques that lead to under-estimates of the firm's production costs, whereas other standard earnings management techniques (the second class) such as channel stuffing, delayed write-downs of assets, or "timely" sales of assets do not. Since incentives to use the second class of earnings management techniques are likely to be independent of the incentives to employ the first class, our model predicts that regulatory increases in the cost of misreporting (e.g., Section 302 of the Sarbanes-Oxley Act of 2002) will result in a change in the distribution of observed earnings management techniques (as, for example, among SEC enforcement actions). In particular, we expect a reduction in the use of the first class of earnings management techniques relative to the second. Second, our analysis suggests that standard measures of profitability will be positively correlated with the use of the first class of earnings management techniques. Third, firms with more similar technologies (e.g., those for whom production is governed by physical or chemical processes or those used in mature industries) will be less likely to employ this type of earnings management than firms with less similar technologies (e.g., service industries or firms that produce a large variety of different products). In addition, our analysis also suggests that the more frequent use of deferred prosecution agreements may lead to unexpected consequences—providing the firm's competitors with incentives to misreport so as to bias estimates of their production costs downward.

Our analysis also appears to support the claims made by C. Michael Armstrong, former CEO of AT&T, that AT&T's *perceived* strategic failures, its inability to compete with WorldCom, and

³¹ See Darrough (1993) or Raith (1996) among others or the excellent survey by Verrecchia (2001).

the decision to break up the company were the result of accounting fraud at WorldCom. He suggests that WorldCom's "revenues were false, margins were false, their costs were false" (McConnell et al. 2002, 1) and that this resulted in layoffs, cost cutting, and, finally, the decision to break up AT&T in order to service its debt. Former Sprint CEO William Estry suggests that his company also struggled with its inability to match WorldCom's performance and noted that: "It never dawned on us the base of their pricing was fraud" (Searcy 2005, C1). Our analyses, particularly when one firm's costs of misreporting are greater than its rival's, are consistent with Armstrong's assertions about the impact of WorldCom's accounting fraud on its competitors.

Finally, we should comment on the impact of our assuming that firms are Cournot competitors. It is well known (e.g., Darrough 1993; Raith 1996) that results may be sensitive to the form of competition assumed because quantity choices are strategic substitutes but price choices are strategic complements. We believe that the only significant impact of assuming Bertrand (price-choosing) rather than Cournot (quantity-choosing) competition in our setting is on the direction of the equilibrium bias in reports. Because prices are strategic complements under Bertrand competition, if the firms choose prices and sell substitute products, then we expect that each would have an incentive to bias reported costs of production up rather than down. Other than the direction of the bias, we believe that the remaining results would be qualitatively similar to those obtained under Cournot competition.

APPENDIX

Proposition 1

If (C1) holds, then there exists a linear equilibrium (q_1^*, q_2^*) to the production game with:

$$q_1^* = N_0 + N_1c_1 + N_2s_1 + N_3s_2$$

$$q_2^* = M_0 + M_1c_2 + M_2s_1 + M_3s_2,$$

where:

$$N_0 = (1/3) \left(a - \frac{(2 - \beta_1)\alpha_0}{4 - \alpha_1\beta_1} + \frac{2(2 - \alpha_1)\beta_0}{4 - \alpha_1\beta_1} \right) \quad M_0 = (1/3) \left(a - \frac{(2 - \alpha_1)\beta_0}{4 - \alpha_1\beta_1} + \frac{2(2 - \beta_1)\alpha_0}{4 - \alpha_1\beta_1} \right)$$

$$N_1 = -\frac{2 - \beta_1}{4 - \alpha_1\beta_1} \quad M_1 = -\frac{2 - \alpha_1}{4 - \alpha_1\beta_1}$$

$$N_2 = -(1/3)\alpha_2 \left(\frac{2 - \beta_1}{4 - \alpha_1\beta_1} \right) \quad M_2 = (2/3)\alpha_2 \left(\frac{2 - \beta_1}{4 - \alpha_1\beta_1} \right)$$

$$N_3 = (2/3)\beta_2 \left(\frac{2 - \alpha_1}{4 - \alpha_1\beta_1} \right) \quad M_3 = -(1/3)\beta_2 \left(\frac{2 - \alpha_1}{4 - \alpha_1\beta_1} \right).$$

Proof

To find a linear equilibrium, compute using the conjectured equilibrium strategies:

$$E[q_2|y_1] = M_0 + M_1E[c_2|y_1] + M_2s_1 + M_3s_2$$

$$E[q_1|y_2] = N_0 + N_1E[c_1|y_2] + N_2s_1 + N_3s_2.$$

Substituting Equations (C2):

$$\begin{aligned}
E[q_2|y_1] &= M_0 + M_1(\beta_0 + \beta_1c_1 + \beta_2s_2) + M_2s_1 + M_3s_2 \\
&= (M_0 + M_1\beta_1) + M_1\beta_1c_1 + M_2s_1 + (M_1\beta_2 + \beta_3)s_2 \\
&= A_0 + A_1c_1 + A_2s_1 + A_3s_2;
\end{aligned} \tag{A1}$$

$$\begin{aligned}
E[q_1|y_2] &= N_0 + N_1(\alpha_0 + \alpha_1c_2 + \alpha_2s_1) + N_2s_1 + N_3s_2 \\
&= (N_0 + N_1\alpha_0) + N_1\alpha_1c_2 + (N_1\alpha_2 + N_2)s_1 + N_3s_2 \\
&= B_0 + B_1c_2 + B_2s_1 + B_3s_2.
\end{aligned} \tag{A2}$$

Substituting into the expressions for q_i for $i = 1, 2$ derived in the text:

$$\begin{aligned}
q_1 &= (1/2)(a - c_1) - (1/2)(A_0 + A_1c_1 + A_2s_1 + A_3s_2) \\
&= (1/2)(a - A_0 - (1 + A_1)c_1 - A_2s_1 - A_3s_2);
\end{aligned} \tag{A3}$$

$$\begin{aligned}
q_2 &= (1/2)(a - c_2) - (1/2)(B_0 + B_1c_2 + B_2s_1 + B_3s_2) \\
&= (1/2)(a - B_0 - (1 + B_1)c_2 - B_2s_1 - B_3s_2).
\end{aligned} \tag{A4}$$

In equilibrium, the expectation of (A3) (resp. (A4)) must coincide with our conjectures. So, taking expectations of (A3) with respect to firm 2's information set (of (A4) with respect to firm 1's information set):

$$E[q_1|y_2] = (1/2)(a - A_0 - (1 + A_1)\mu_0 - (1 + A_1)\mu_1c_2 - [(1 + A_1)\mu_2 - A_2]s_1 - A_3s_2)$$

$$E[q_2|y_1] = (1/2)(a - B_0 - (1 + B_1)\xi_0 - (1 + B_1)\xi_1c_1 - B_2s_1 - [(1 + B_1)\xi_2 + B_3]s_2).$$

The proof is completed by matching the coefficients in Equations (A1) and (A3) and Equations (A2) and (A4), solving the resulting system of equations for the A 's and B 's and then solving for the M 's and N 's. ■

Proposition 2

In every linear equilibrium, (q_1^*, q_2^*) are defined as in Proposition 1 and (s_1^*, s_2^*) satisfy:

$$s_1^* = D_0 + D_1c_1 + D_2k_1$$

$$s_2^* = F_0 + F_1c_2 + F_2k_2,$$

where:

$$E[c_2|c_1] = \mu_0 + \mu_1c_1$$

$$E[c_1|c_2] = \delta_0 + \delta_1c_2$$

$$D_0 = \frac{1}{\varepsilon_1 - A_2^2}[-A_2(a - A_0 + A_3F_0 + A_3F_1\mu_0)] \quad F_0 = \frac{1}{\varepsilon_2 - B_3^2}[-B_3(a - B_0 + B_2D_0 - B_2D_1\delta_0)]$$

$$D_1 = \frac{1}{\varepsilon_1 - A_2^2}[A_2(1 + A_1) - A_2A_3F_1\mu_1 + \varepsilon_1] \quad F_1 = \frac{1}{\varepsilon_2 - B_3^2}[B_3(1 + B_1) - B_2B_3D_1\delta_1 + \varepsilon_2]$$

$$D_2 = -\left(\frac{1}{\varepsilon_1 - A_2^2}\right) \quad F_2 = -\left(\frac{1}{\varepsilon_2 - B_3^2}\right).$$

Proof

To find a linear equilibrium, compute using the conjectured equilibrium strategies:

$$E[s_2|c_1] = F_0 + F_1 E[c_2|c_1]$$

$$E[s_1|c_2] = D_0 + D_1 E[c_1|c_2],$$

where $E[k_j | k_i, c_i] = E[k_j | c_i] = E[k_j] = 0$ by independence and our assumption that $E[k_i] = 0$ for $i = 1, 2$. Further, since c_1, c_2 are joint normally distributed, $E[c_2 | c_1] = \mu_0 + \mu_1 c_1$ and $E[c_1 | c_2] = \delta_0 + \delta_1 c_2$. Substituting into Equations (4) and (5) and using the definitions of the A 's and B 's:

$$s_1 = \left[\frac{1}{\varepsilon_1 - A_2^2} \right] \left[-A_2(a - A_0 + A_3 F_0 + A_3 F_1 \mu_1) + (A_2(1 + A_1) - A_2 A_3 F_1 \mu_1 + \varepsilon_1) c_1 - k_1 \right]$$

$$s_2 = \left[\frac{1}{\varepsilon_2 - B_3^2} \right] \left[-B_3(a - B_0 + B_2 D_0 + B_2 D_1 \delta_0) + (B_3(1 + B_1) - B_2 B_3 D_1 \delta_1 + \varepsilon_2) c_2 - k_2 \right].$$

Since both are of the form assumed, the linear equilibrium is obtained by setting the coefficients in these equations equal to the F 's and D 's, respectively. ■

Proposition 3

If k_1 and k_2 are common knowledge, then there is no monotone equilibria in pure strategies.

Proof

Suppose not. Then in such an equilibrium, firm i can invert the strategy defining its rival's choice of s_j and infer c_j . Thus, the second-stage game is now a game of complete information whose solution is well-known: $q_i^* = (1/3)(a - 2c_i + c_j)$ and equilibrium profits are $(q_i^*)^2$, for $i = 1, 2$. Next, consider a deviation in which firm i reports \hat{s}_i , which leads firm j to infer that firm i 's cost of production is $\hat{c}_i \neq c_i$. Thus, $q_i = (1/3)(a - c_i - \hat{c}_i + c_j)$ and $q_j = (1/3)(a - 2c_j - \hat{c}_i)$. Since firm i 's profits are q_i^2 , they are decreasing in \hat{c}_i . As a result, if firm i deviates to $\hat{c}_i < c_i$, then its profits in the product market increase, which, for small deviations, exceed the costs of misreporting making firm i 's deviation profitable and showing that there is no linear perfect Bayes equilibrium in pure strategies when k_1 and k_2 are common knowledge. ■

Proposition 4

If ε is not too small, then there is a symmetric linear perfect Bayes equilibrium in pure strategies.

Proof

In a symmetric equilibrium, $D_i = F_i$ and $\alpha_i = \beta_i$ for $i = 1, 2, 3$; and $N_i = M_i$ for $i = 1, 2, 3, 4$ and $\mu_i = \delta_i$ for $i = 1, 2$. After matching coefficients, we have 12 nonlinear equations in 12 unknowns describing the coefficients of the firms' strategies. By iterative substitution, one obtains a system of two equations in two unknowns, D_1, D_2 (resp. F_1, F_2). One equation is quadratic in D_1 and has real roots when $\varepsilon_1 (= \varepsilon_2)$ is not too small. Solving for the roots and substituting into the other equation produces an 18th order polynomial in D_2 with 87 sign changes. Thus, by Descartes' Rule of Signs (see, for example, Levin [2002] and the references therein), there is at least one real root and, thus, at least one symmetric linear equilibrium in pure strategies. ■

Proof of the Comparative Static Results for Changes in ε

Suppose not. Then in equilibrium, $s_i - c_i > \xi_i > 0$ for $i = 1, 2$ for all ε . Since $E[\pi_i | k_i, c_i] = E[(q_i^*)^2 | k_i, c_i] - h_i(s_i, c_i)$ and $E[(q_i^*)^2]$ is bounded from above by the firm's mo-

nopoly profits, $[(a - c_i) / 2]^2$, if $s_i - c_i > \xi_i > 0$, then there is a ε large enough so that $[(a - c_i) / 2]^2 - h_i(s_i, c_i) < 0$. Thus, if $s_i - c_i > \xi_i > 0$, there exists a large enough ε so that in the conjectured equilibrium, firm i 's expected profits are negative. Since firm i could deviate to $s_i = c_i$ and earn non-negative profits, such a deviation is profitable and we have shown that in every linear perfect Bayes equilibrium, $s_i - c_i > \xi_i > 0$ for all ε must be false. Given this, the difference $s_i - c_i$ must become arbitrarily small as ε gets large, which implies that $E[c_i | c_j, s_i, s_j] - c_i$ also becomes arbitrarily small as ε becomes arbitrarily large. Finally, since q_i^* is a linear function of c_i and $E[c_j | c_i, s_i, s_j]$ in equilibrium, it too converges to the complete information Cournot output as ε becomes arbitrarily large. ■

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