Insider Trading, Competition, and Real Activities Manipulation*

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Abstract

Corporate insiders, particularly managers, not only have access to their firms' private information, but also control over their firms' operational decisions. In this paper, we consider a setting where managers manipulate the firms' real activities in anticipation of subsequent insider trading opportunities. We find these managers choose production quantities that are strictly higher than the quantities absent insider trading. The overproduction leads to lower firm profits but higher consumer surplus. When we allow the managers to trade both in their own firms' and their rival firms' stocks, we find that the competition among insiders in the financial market drives down the expected insider trading profits and their incentives to distort production decisions. We then discuss the scenario of "substitute trading" when the managers only trade in their rival firms' shares, and show that the managers can earn some insider benefits without sacrificing their firms' profitability. We also explore the possibility of endogenizing the managers' ownership through compensation contracts.

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1 Introduction

Managers often use accounting discretion to profit from insider trades. Numerous analytical studies (Kim and Verrecchia, 1994; Bushman and Indjejikian, 1995; Huddart, Hughes, and Levine, 2001; etc.) demonstrate disclosure strategies adopted by the managers to increase insider trading gains. Empirical evidence confirms that managers use nonpublic information or biased disclosures for higher insider trading profits (Penman, 1982; Elliott, Morse and Richardson, 1984; Rogers and Stocken, 2005; Rogers, 2008; Jagolinzer, 2009; etc.). In this study, we show that managers could also obtain insider trading benefits by manipulating real operating activities, which has not been examined by prior research.

The "insiders" in the context of insider trading are often directors, officers, or other key employees of the firms. In addition to access to the firms' private information, these corporate insiders typically have control over the firms' operations. Therefore, they have the opportunity to use the firms' real activities to benefit themselves.[1] In this paper, we examine how managers could exploit operating decisions to maximize their private benefits from insider trading. Specifically, we focus on the interaction of managers' production decisions and stock trading decisions, as well as the role of information in this joint decision process.

We first consider an insider who is the manager of a monopolistic firm that faces a product market with uncertain demand. The manager learns an imperfect accounting signal about the market demand, before he chooses the production output quantity for the firm. Subsequently, the manager has the opportunity to trade in the firm's securities for private benefits in a Kyle setting. We find allowing the manager to trade in the firm's securities creates incentives for the manager to increase production quantity to a level strictly higher than optimal absent insider trading.

This is because the manager's expected insider trading gain is a function of the volatility of the firm's profit. A more volatile firm profit implies more informational asymmetry in the financial market, as well as a higher insider trading gain the manager can obtain. In our model, a higher production quantity amplifies the variance of the firm's future profit, thus leading to more private benefits for the manager, but at the expense of firm value. Since we assume the manager also has an equity stake in the firm value, he must trade off the loss of value in the firm and his personal gain from insider trading when choosing the production quantity.

This result is largely consistent with the conventional wisdom that insider trading is detrimental to firm value. However, the effect of the upwardly distorted production quantity on social welfare may be quite different – as higher production output often leads to increased consumer surplus. From a regulatory perspective, this benefit should be balanced against the well-understood costs of information asymmetry in the capital markets on market liquidity.

We then extend the monopoly setting to a duopoly setting by letting two firms compete in a Cournot market. In addition, we allow the managers to trade 1) only in their own firms' stocks, or 2) in both their own and rival firms' stocks. Again, we find that the equilibrium production quantities

[1] In fact, research shows that managers often use real activities opportunistically in many other settings, such as to avoid reporting loss (Roydhowdhury, 2006) or to meet earnings benchmarks (Gunny, 2010).

are upwardly distorted from the profit-maximizing levels in both cases, with greater distortions in the first case. This is because in the second case, more insiders in the financial market compete the ex-ante expected insider trading gains away, which in turn reduces the managers' incentives to distort production quantities. Clearly, less deviation from optimality leads to higher firm profit and firm value. However, lower production output could also imply lower consumer surplus.

An interesting third scenario we explore is when the managers *only* trade in their rival firms' stocks. This could happen when the managers are forbidden from trading their own firms' securities. In legal terms, this trading mechanism is a type of "substitutes for insider trading", which describes when a manager trades in the stocks of a firm whose realized value is correlated with his own firm's (Ayres and Bankman, 2001; Huang, 2006). In our setting of substitute trading, the managers essentially become complete insiders of their rival firms, while not being able to control the rival firms' operations. Thus they do not distort production quantities of their own firms, but can enjoy benefits from insider trading. As long as no collusion is allowed between the two rival firms, substitute trading does not impair firm value.

When performing comparative statics, we see that the production quantity distortion and expected insider trading gain decrease in the manager's current equity stake in the firm, while the expected firm value increases in the stake. This is intuitive because the manager's incentive is more aligned with the shareholders when his stake in the firm is high.[2] The precision of the firm's accounting signal is also important. The more accurate the signal, the lower the expected trading profit for the manager, and the less pronounced the incentive for the manager to distort production quantities. Thus, the precision of information is positively related to the expected final firm value. This result is largely consistent with empirical evidence provided by prior studies such as Welker (1995), Lang and Lundholm (1996), Botosan (1997), Healy, Hutton and Palepu (1999), and Leuz and Verrecchia (2000).

Finally, we explore the possibility of endogenizing the manager's interest in the firm value, perhaps through a contract when the manager is hired. Baiman and Verrecchia (1995, 1996) consider principal-agent settings where the principal offers a linear contract to the agent extracting the agent's anticipated profits from subsequent insider trading. That is, the insider trading profits are expected to be part of the manager's implicit compensation, making it cheaper to hire and retain managers. Following this setting, we allow the managers to be granted a linear contract with a fixed pay and a portion of restricted stock of the firm, in addition to the expected insider trading gain he will later obtain. To keep the setting simple, we still assume the managers are risk neutral. It turns out the optimal portion of stock granted results from a trade-off between the firm value that increases in the manager's portion of stock, and the insider trading gain that decreases in it. There is indeed an interior solution for the optimal stock granted in the contract in the monopoly setting. However, only a corner solution exists in the duopoly setting involving selling the whole firm to the manager, because the increase in firm value dominates the decrease in the insider trading gain within the reasonable range of $[0, 1]$.

[2]Please note that the effects of the manager's stake hold true in all scenarios of the model *except* with subtitute trading, in which case the manager's stake doesn't matter.

We contribute to the extant literature in three ways. First, we are the first to examine the effect of insider trading on managers' manipulation of real activities. While prior research focuses on managers using their informational advantages and/or disclosure strategies to increase personal trading gains, our results imply that managers can also exploit their control over their firms' operations for the same purpose. Further, we demonstrate the manager's actions affect not only his own firm, but also the consumers and society at large.

Second, our results shed light on the interaction between financial markets and product markets. We find that the competition among insiders in the financial market drives down their informational advantage, a finding similar to that of Holden and Subrahmanyam (1992). Further, we find that competition in the financial market in turn dampens the competition in the product market, which implies an implicit substitutability of these two markets. Thus, policy-makers should take into consideration the potential effect on one market while regulating the other.

Third, our modelling design circumvents the violation of normality assumption that often occurs when financial market models are combined with production decisions.[3] Specifically, since the firm value is a function of the squared term of the production output quantity, it may lose its normal distribution if the uncertainty is contained in the quantity. We maintain the normality assumption by only letting the manager observe the realized market demand *after* his production decision. This ensures that the production quantity is always a constant in equilibrium and the final firm value as a function of the quantity is well behaved.[4]

Our results are readily testable with empirical data. We predict that a firm whose CEO has stock ownership is less likely to engage in real activities manipulation, i.e., overproduction. However, the degree of competition within the industry in which the firm operates could mitigate the overproduction problem. The more competitive the industry, the less likely the participating firms overproduce, holding the CEOs' stock ownership equal. The precision of accounting information should also be inversely related to the executives' manipulation of real activities.

Please note although we comment on the welfare effects of insider trading, we do not intend to evaluate its legality in this paper. The political and academic discussion surrounding insider trading is long-standing.[5] Under U.S. law, insider trading can be legal or illegal. While corporate insiders can trade their firms' stocks legally in compliance with government regulations and their firms' policies, the SEC refers to illegal insider trading as "*buying or selling a security, in breach of a fiduciary duty*

[3] See Bagnoli et al. (2001) and Noeldeke and Troeger (2001) for the necessary and sufficient conditions for the existence of a linear equilibrium in the Kyle model.

[4] This is of course not the only way to maintain the normality of firm value. When facing similar technical issues, Jain and Mirman (2000, 2002) introduce uncertainty as a multiplicative term of the demand function. The drawback of their approach is that the second order condition is not always satisfied.

[5] For example, Manove (1989) shows that insider trading discourages investment and reduces efficiency. Ausubel (1990) and Fishman and Hagerty (1992) show that insider trading decreases the informativeness of a firm's stock price. Glosten (1989) and Leland (1992) show that insider trading decreases the firm's market liquidity. On the other hand, Manne (1966) argues that insider trading helps reduce agency problems by aligning the interests of the shareholders and managers of a firm. Bernhardt, Hollifield, and Hughson (1995) find that insider trading expedites the dissemination of private information and the price discovery process. Bhattacharya and Nicodano (2001) show that insider trading could improve risk-sharing among noise traders with stochastic liquidity needs. Laux (2010) demonstrates that investment decisions, specifically related to the abandonment of projects, can be improved when managers are allowed to time their trading activities based on insider information.

or other relationship of trust and confidence, while in possession of material, nonpublic information about the security."[6] Previous studies on insider trading in finance, law, and economics often focus on whether insider trading should be allowed. In this paper, however, we intend to examine the "real" effects of insider trading - how insider trading opportunities affect the preceding operating decisions made by firm managers.

Our study is related to prior research on financial market information and real activities. Gao and Liang (2013) evaluate a firm's optimal disclosure policy for the secondary stock market and associated effects on real investment decisions. The traders in the secondary market possess privately-acquired information about the firm, which is reflected in stock price through trading, and "fed back" into the firm's real investment decisions. Accounting disclosure reduces the informational asymmetry between the insiders and noise traders, but may also lead to a less informative stock price and decreased investment efficiency. Gao and Liang (2013) focus on the "feedback" effect on a firm's investment decision of the investors' private information impounded in the stock price. The investors in our study, however, do not have any private information and merely serve as liquidity traders.

Several prior studies also examine insider trading and accounting disclosure in various settings. Kim and Verrecchia (1994) find accounting disclosures could actually lead to increased information asymmetry and less liquidity in a Kyle setting. Bushman and Indjejikian (1995) also show that disclosure of private information can actually increase the managers' personal gain from insider trading by crowding out other informed traders from the financial market. Huddart et al. (2001) examine the case when insiders must publicly disclose their trades after these trades are completed. As a result, the insiders adopt a dissimulation strategy by adding noise in their orders. None of these studies explicitly consider operating decisions or product market competition.

The rest of the paper is organized as follows: Section 2 introduces the basic model in a single-firm setting. Sections 3 extends the analyses to a two-firm setting. Section 4 further discusses the possibility of contracting. Section 5 concludes the paper.

2 The basic model

In the basic model, we consider a monopolistic firm that produces and sells a product to consumers. It faces a linear inverse demand function $p = \widetilde{a} - q$, where p is the unit price for its product; $\widetilde{a}$ is the intercept of market demand; and q is the output quantity. The market demand is uncertain, with $\widetilde{a} \sim N(m_a, \Sigma_a)$, and is only realized after the production quantity decision has been made.[7] Without loss of generality, we assume the firm's marginal cost is 0.

The firm is run by a risk-neutral manager, who is responsible for the firm's operations. At the beginning of the game, the manager receives a noisy interim signal $\widetilde{s}$, generated by the firm's

[6] See http://www.sec.gov/answers/insider.htm for more details.

[7] A normally distributed $\widetilde{a}$, although a common assumption (e.g. Darrough, 1993; Clinch and Verrecchia, 1997), opens up the possibility of negative production quantities in equilibrium. We assume m_a is sufficiently large that the possibility of negative production is small. Further, negative production can be understood as converting the products back into its original cost components under a reversible production technology. See Christensen and Feltham (2005) for a brief review on this topic.

accounting system. For convenience, we define the accounting information in the model as a signal about the market demand $\widetilde{a}$.[8] The signal equals $\widetilde{s} = \widetilde{a} + \widetilde{\theta}$, with $\widetilde{\theta} \sim N(0, \Sigma_\theta)$. The precision of the signal, $\frac{1}{\Sigma_\theta}$, represents the accuracy of accounting information. After receiving the signal $\widetilde{s}$, the manager discloses it publicly.[9]

The manager has a subsequent opportunity to trade in the firm's shares. Following Kyle (1985), we consider three types of participants in the stock market. The first type is a risk-neutral competitive market maker, who sets the pricing rule and makes zero trading profits. The second type is the noise traders who, for exogenous reasons such as liquidity needs, trade randomly. The third type is the insider-manager who makes the quantity decision for his firm before observing the final market demand $\widetilde{a} = a$. The demand submitted by the manager is denoted $\widetilde{d}$, and the demand of the noisy trader is denoted $\widetilde{u} \sim N(0, \Sigma_u)$. The market maker observes the combined total order flow $\widetilde{D} = \widetilde{d} + \widetilde{u}$, but cannot distinguish d or u separately. She then sets the market clearing price for the firm's stock, P.

To introduce tension into the model, we presume that the manager also has some interest in the firm's final profit, V. Perhaps he is concerned with his own job prospect, hence the firm's long-term survival. Or, he may own a certain amount of restricted stock that he was granted at a prior date. In either case, we assume the manager's stake in the firm value is $0 < \omega \leq 1$.[10] That is, in addition to the expected insider trading gains, the manager also cares about ωV. Thus, he chooses the production quantity to maximize the sum of Π and ωV, his expected insider trading gains and his equity stake in the firm, respectively. In the basic model, we assume away any other compensation the manager may get from the firm.

The timeline of the events is as follows.

1. The firm's accounting system produces a noisy signal $\widetilde{s}$, which the manager learns and discloses publicly.

2. The manager makes production quantity decision q.

3. The market demand a is realized, as well as the final firm value V, both privately observed by the manager.

4. The manager submits his order d, while the noisy trader submits u, to the market maker to trade shares.

5. The market maker receives a total order flow D and executes the trades.

In summary, the scenario described is a two-stage game involving production quantity decision followed by a Kyle (1985) model. The solution concept we use is a perfect Bayesian equilibrium

[8] In reality, the interim accounting signal can also be about the firm's cost or profit. Whether the signal is about demand, cost or profit does not matter in the analyses, since their effects on the final firm value are qualitatively equivalent.

[9] We assume the manager always publicly discloses the signal $\widetilde{s}$. This ensures that the probability distribution of the final firm value is common knowledge for all market participants, which is assumed in the Kyle setting, as well as most of the financial market models.

[10] In a later discussion, we explore the possibility of an endogenous ω.

derived through backward induction. The manager in our setting has two decision variables: the firm's production quantity and his own trading decision in the firm's shares. The market maker's problem is to set price for the firm's stocks. We focus on linear strategies of the players, and evaluate the impact of subsequent insider trading on the firm's operating decisions.

2.1 When insider trading is not allowed

We first analyze the manager's strategy absent insider trading. When he receives a signal $\widetilde{s} = \widetilde{a} + \widetilde{\theta}$ and discloses it to the public, the belief of the market demand is updated to $(a|s) \sim N\left(\frac{\Sigma_a s + \Sigma_\theta m_a}{\Sigma_a + \Sigma_\theta}, \frac{\Sigma_a \Sigma_\theta}{\Sigma_a + \Sigma_\theta}\right)$. If insider trading is impossible, the manager would simply maximize his stake in the expected firm value. His objective function is

$$\max_q \omega \left(q(E[a|s] - q)\right). \quad (1)$$

The optimal production quantity chosen by the manager is

$$q^* = \frac{1}{2}E[a|s] = \frac{1}{2}\frac{\Sigma_a s + \Sigma_\theta m_a}{\Sigma_a + \Sigma_\theta}.$$

Since the market demand is uncertain, the firm value is thus

$$\widetilde{V}(s, \widetilde{a}) = \frac{1}{2}q^*(\widetilde{a} - q^*).$$

It is easy to see that the firm value is normally distributed, with q affecting both the mean and the variance of the firm value, $\widetilde{V} \sim N\left(\frac{1}{4}\left(\frac{\Sigma_a s + \Sigma_\theta m_a}{\Sigma_a + \Sigma_\theta}\right)^2, \frac{1}{4}\left(\frac{\Sigma_a s + \Sigma_\theta m_a}{\Sigma_a + \Sigma_\theta}\right)^2 \frac{\Sigma_a \Sigma_\theta}{\Sigma_a + \Sigma_\theta}\right)$.

2.2 When insider trading is allowed

Next we examine the scenario when insider trading is allowed. After learning the accounting signal $\widetilde{s}$, the manager chooses production quantity $\widehat{q}$ at time 2 so as to maximize his total payoff, which is the sum of his equity stake in the firm and his expected insider trading gains

$$E\left[\omega\widetilde{V}(\widehat{q})\right] + E[\Pi(\widehat{q})]. \quad (2)$$

Given $\widehat{q}$, the firm value is $\widetilde{V} \sim N\left(\widehat{q}(E[a|s] - \widehat{q}), \widehat{q}^2\frac{\Sigma_a \Sigma_\theta}{\Sigma_a + \Sigma_\theta}\right)$. The manager then observes the realized market demand $\widetilde{a} = a$, or $\widetilde{V} = V$ at time 3. He and the noise traders both submit their demands, d and u, respectively, for the firm shares to the market maker at time 4. The manager does not observe the noise traders' demand $\widetilde{u}$. He chooses his demand d so as to maximize his personal trading profit

$$E\left[(V - P(D))d|\widetilde{V} = V\right]. \quad (3)$$

Finally, at time 5, the total order flow received by the market maker is $\widetilde{D} = \widetilde{d} + \widetilde{u}$. She sets the market clearing price by setting

$$P(D) = E[V|D = d + u]. \tag{4}$$

As is standard in the Kyle model, we focus on linear strategies of the players. That is, the manager uses a linear strategy in determining his demand by setting

$$d(V) = \alpha + \beta V, \tag{5}$$

and the market maker uses a linear pricing rule

$$P(d + u) = \mu + \lambda(d + u). \tag{6}$$

We derive the manager's equilibrium production quantity using backward induction. That is, we first solve the market maker's price-setting strategy and the manager's demand order strategy, so that we could compute the manager's ex-ante expected insider trading gains $E[\Pi]$ for any given $\widehat{q}$. We then plug $E[\Pi(\widehat{q})]$ and $E[V(\widehat{q})]$ into the manager's objective function and solve for $\widehat{q}$.

Proposition 1. *In a monopoly product market with subsequent insider trading, there exists a unique linear equilibrium characterizing the strategies of the manager and the market maker as follows:*

$$\begin{aligned} \alpha &= -\frac{\sqrt{\Sigma_u}}{\sqrt{\frac{\Sigma_a \Sigma_\theta}{\Sigma_a + \Sigma_\theta}}} \left(E[a|s] - \widehat{q}\right), \ \beta = \frac{\sqrt{\Sigma_u}}{\widehat{q}\sqrt{\frac{\Sigma_a \Sigma_\theta}{\Sigma_a + \Sigma_\theta}}}, \\ \mu &= \widehat{q}\left(E[a|s] - \widehat{q}\right), \ \lambda = \frac{\widehat{q}}{2\sqrt{\Sigma_u}}\sqrt{\frac{\Sigma_a \Sigma_\theta}{\Sigma_a + \Sigma_\theta}}, \end{aligned}$$

and

$$\widehat{q} = \frac{1}{2}\left(E[a|s]\right) + \frac{1}{4\omega}\sqrt{\frac{\Sigma_u \Sigma_a \Sigma_\theta}{\Sigma_a + \Sigma_\theta}}.$$

Proof. See appendix.

Proposition 1 presents a result similar to that of a one-period Kyle model, but incorporating a real production decision by the manager. Allowing insider trading distorts the manager's incentive when making the quantity decision for his firm. Since the mean and the variance of the final firm value are both functions of $\widehat{q}$, the quantity decision affects the manager's subsequent trading decision, as well as the market maker's pricing strategy.

When insider trading is banned, the production quantity is $q^* = \frac{1}{2}(E[a|s])$. When insider trading is allowed, the production quantity is $\widehat{q} = q^* + \frac{1}{4\omega}\sqrt{\frac{\Sigma_u \Sigma_a \Sigma_\theta}{\Sigma_a + \Sigma_\theta}}$. Production quantity is thus always higher when insider trading is allowed. This result occurs because the manager's ex-ante trading profits, $E[\Pi] = \frac{\widehat{q}}{2}\sqrt{\frac{\Sigma_u \Sigma_a \Sigma_\theta}{\Sigma_a + \Sigma_\theta}}$, are increasing in $\widehat{q}$. The manager thus has incentives to increase the production quantity beyond the profit-maximizing level. Further, $\widehat{q}$ converges to q^* as ω increases, since the manager's incentive to distort production decreases.

One implication of Proposition 1 is the potentially improved consumer welfare as a result of insider trading. When the manager of the monopolistic firm has the opportunity to trade as an insider, the production quantity will be upwardly distorted. The consumers of the real good will therefore enjoy the lower selling price of the firm's products, hence higher consumer surplus.

Corollary 1.1. *In a monopoly product market with subsequent insider trading, the manager's ex-ante expected trading profit is*

$$E[\Pi] = m_a \sqrt{\frac{\Sigma_u \Sigma_a \Sigma_\theta}{\Sigma_a + \Sigma_\theta}} + \frac{1}{2\omega} \frac{\Sigma_u \Sigma_a \Sigma_\theta}{\Sigma_a + \Sigma_\theta},$$

which decreases in the manager's stake in the firm ω and accounting precision $\frac{1}{\Sigma_\theta}$.

Proof. See appendix.

The result presented in Corollary 1.1 is intuitive. The manager's ex-ante trading profit is a function of the variance of the firm's value. The higher the firm value's variance, the higher the informational advantage the insider has. Thus, the precision of the accounting signal affects the manager's expected trading profit in a negative way. The more precise the accounting signal is, the less trading profit the manager can expect.

Corollary 1.2. *In a monopoly product market with subsequent insider trading, the ex-ante expected firm profit is*

$$E\left[\widetilde{V}\right] = \frac{m_a^2}{4} - \frac{1}{16\omega^2} \frac{\Sigma_u \Sigma_a \Sigma_\theta}{\Sigma_a + \Sigma_\theta},$$

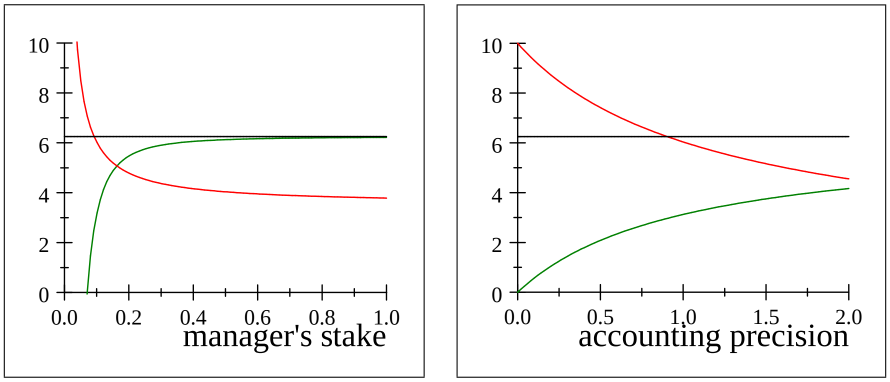
which increases in the manager's stake in the firm ω and accounting precision $\frac{1}{\Sigma_\theta}$.

Proof. See appendix.

When insider trading is impossible, the expected firm profit is $\frac{1}{4}\left(E\left[\frac{\Sigma_a \widetilde{s} + \Sigma_\theta m_a}{\Sigma_a + \Sigma_\theta}\right]\right)^2 = \frac{m_a^2}{4}$. The expected firm profit is thus lower when insider trading is allowed. The ex-ante expected firm profit with insider trading is lower than the monopoly profit due to the distorted quantity decision. Essentially, the manager trades off his current stake in the firm and his personal gain from insider trading when making the production quantity decision. Thus, the higher the manager's current stake in the firm, the less distortion in his quantity decision, and the higher the firm profit.

We can also see that the expected ex-ante firm profit increases in the accounting precision $\frac{1}{\Sigma_\theta}$. This result occurs because accounting precision reduces the manager's ex-ante trading profit and thus his incentives to distort the quantity decision. A very precise accounting signal would thus prevent managers from engaging in subsequent insider trading, and hence improve total firm value.

The results of the two corollaries can be illustrated through Figure 1.



Black: firm value without insider trading; Green: firm value with insider trading;

Red: ex-ante expected insider trading profits

Figure 1: Firm value and insider trading profit as a function

of manager's stake and accounting precision.

We can see that the firm value is constant in ω and Σ_θ when insider trading is not allowed. However, the introduction of insider trading opens up two sources of inefficiency: the misaligned managerial interest and the noisy information. The firm value increases with the manager's interest in the firm and the degree of precision of the firm's accounting signal. On the contrary, the manager's ex-ante expected insider trading profit decreases with the manager's stake and the accounting signal precision.

3 Two-firm setting

The monopoly case shows how subsequent insider trading could affect a manager's operating decision in a single firm setting. Next we expand the case into a duopoly in which two firms, denoted as i, j $(i, j = 1, 2)$, compete in a Cournot product market. For convenience, we assume the two firms/managers are identical and play symmetric strategies in both the financial and product markets. Having two firms significantly affects in both the product market and the financial market in our model. In addition to the expected change in product quantity decisions, it also changes the managers' expected insider trading gain as well as their trading behavior.

The timeline is the same as in the monopoly case. We assume the two firms manufacture the same product. The two firms' shares are both traded in the stock market. The linear inverse demand function for the product is now $p = \widetilde{a} - q_i - q_j$, where q_i and q_j are the output quantities produced and sold by each firm, respectively. Further, the two firms face a common market demand $\widetilde{a} \sim N(m_a, \Sigma_a)$,[11] which is realized after the firms choose their production quantities.

[11] Our assumption of common market demand simplifies the proofs but is not critical. When the two firms have firm-specific demand information, all the major results remain qualitatively the same. This is because the information on the market demand is imperfect but unbiased. One signal from each firm about the common demand allows the firms to update their information twice. However, when the information is about uncorrelated firm-specific demand,

Each of the two firms is run by a hired manager. The manager i receives a noisy interim accounting signal $\widetilde{s}_i = \widetilde{a} + \widetilde{\theta}_i$, $i = 1, 2$, with $\widetilde{\theta}_1$ and $\widetilde{\theta}_2$ being independent and identically distributed. The managers then disclose their respective signals to the public before they make production decisions. Then they observe the final product market demand $\widetilde{a} = a$, before trading in the financial market. We denote manager i's demand for firm i's shares as $\widetilde{d}_{ii}$, and his demand for firm j's shares as $\widetilde{d}_{ij}$. The market maker i observes the total order flow $\widetilde{D}_i$ for firm i's share, which include the order submitted by the insiders and the liquidity trader's order u. She then sets the market clearing price for the firm i's stock, P_i.

3.1 When insider trading is not allowed

When insider trading is not allowed, the manager of each firm simply maximizes his own stake in the firm. After the managers disclose their signals s_1 and s_j, they both get to use the two signals to update their belief about the market demand to $(a|s_i, s_j) \sim N\left(\frac{\Sigma_\theta m_a + \Sigma_a(s_i+s_j)}{2\Sigma_a+\Sigma_\theta}, \frac{\Sigma_a \Sigma_\theta}{2\Sigma_a+\Sigma_\theta}\right)$. Manager i's problem is:

$$\max_{q_i} \omega \left(q_i(E\left[a|s_i, s_j\right] - q_i - q_j)\right). \tag{7}$$

Manager j's problem is symmetric. Solving for the production quantity as in a standard Cournot problem, we have

$$q_i^* = \frac{1}{3} E\left[a|s_i, s_j\right] = \frac{1}{3} \frac{\Sigma_\theta m_a + \Sigma_a \left(s_i + s_j\right)}{2\Sigma_a + \Sigma_\theta}.$$

By plugging q_i^* and q_j^* into the firm's profit function, we can obtain the corresponding profit for firm i $\widetilde{V}_i\left(s_i, s_j, \widetilde{a}\right) \sim N\left(\frac{1}{9}\left(\frac{\Sigma_\theta m_a + \Sigma_a(s_i+s_j)}{2\Sigma_a+\Sigma_\theta}\right)^2, \frac{1}{9}\left(\frac{\Sigma_\theta m_a + \Sigma_a(s_i+s_j)}{2\Sigma_a+\Sigma_\theta}\right)^2 \frac{\Sigma_a \Sigma_\theta}{2\Sigma_a+\Sigma_\theta}\right)$.

3.2 When managers only trade in their own firms' stocks

Now we examine the scenario when insider trading is allowed. We first consider the case when each manager trades in his own firm's stock only. That is, we let $d_{ii} = d_i$ and $d_{ij} = 0$. In this case, the two firms compete in a duopolistic product market, but their managers still act as the monopolistic insiders of their respective stocks in the financial market. Thus, the second stage of the game (Kyle model) is similar to that of the monopoly setting, while the first stage of the game (Cournot) is different.

The manager i has two decision variables. First, he chooses production quantity $\widehat{q}_i$ so as to maximize his total payoff

$$E\left[\omega \widetilde{V}_i\left(\widehat{q}_i\right)\right] + E\left[\Pi_i\left(\widehat{q}_i\right)\right]. \tag{8}$$

Second, he chooses his demand for his firm's share, d_i, so as to maximize his total trading profit

$$E\left[\left(V_i - \widetilde{P}_i\left(\widetilde{D}_i\right)\right) d_i | \widetilde{V}_i = V_i\right]. \tag{9}$$

one signal each firm will only allow the firms to update their information once, on their own specific demand. Therefore, the assumption of common market demand only results in more precision than firm-specific demand.

In the second stage of the game, the market maker determines the market clearing price for firm i's stock by setting

$$P_i\left(D_i\right) = E\left[V_i | D_i = d_i + u\right]. \tag{10}$$

Again, we focus on the players' linear strategies. Manager i's is

$$d_i\left(V_i\right) = \alpha_i + \beta_i V_i, \tag{11}$$

and the market maker i's pricing rule is

$$P_i\left(d_i + u\right) = \mu_i + \lambda_i\left(d_i + u\right). \tag{12}$$

After the firms disclose s_1 and s_j, all players update their beliefs about the product market demand to $(a|s_i, s_j) \sim N\left(\frac{\Sigma_\theta m_a + \Sigma_a(s_i+s_j)}{2\Sigma_a+\Sigma_\theta}, \frac{\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}\right)$. Plugging $\widehat{q}_i$ and $\widehat{q}_j$ into firm i's profit function, we get $\widetilde{V}_i \sim N\left(\widehat{q}_i\left(E\left[a|s_i, s_j\right] - \widehat{q}_i - \widehat{q}_j\right), \ \widehat{q}_i^2 \frac{\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}\right)$. We then use backward induction to solve for the manager's and the market maker's linear strategies, and the equilibrium production quantity.

Proposition 2. *In a Cournot product market with subsequent insider trading where the managers only trade in their own firms' shares, there exists a unique linear equilibrium characterizing the strategies of the manager i and the market maker i, where i, j = 1, 2, as follows:*

$$\alpha_i = -\frac{\sqrt{\Sigma_u}}{\sqrt{\frac{\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}}}\left(E\left[a|s_i, s_j\right] - \widehat{q}_i - \widehat{q}_j\right), \ \beta_i = \frac{\sqrt{\Sigma_u}}{\widehat{q}_i\sqrt{\frac{\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}}},$$
$$\mu_i = \widehat{q}_i\left(E\left[a|s_i, s_j\right] - \widehat{q}_i - \widehat{q}_j\right), \ \lambda_i = \frac{\widehat{q}_i}{2\sqrt{\Sigma_u}}\sqrt{\frac{\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}},$$

and

$$\widehat{q}_i = \widehat{q}_j = \frac{1}{3}E\left[a|s_i, s_j\right] + \frac{1}{6\omega}\sqrt{\frac{\Sigma_u\Sigma_a\Sigma_\theta}{2\Sigma_a + \Sigma_\theta}}.$$

Proof. See appendix.

In comparison with Proposition 1 about a quantity-setting manager in a monopoly, the results in Proposition 2 reflect the change in the nature of the product market structure. Comparing the manager's quantity decisions when insider trading is not possible, $q_i^* = \frac{1}{3}E\left[a|s_i, s_j\right]$; and the managers' quantity decisions when insider trading is allowed, $\widehat{q}_i = q_i^* + \frac{1}{6\omega}\sqrt{\frac{\Sigma_u\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}}$; obviously we have $\widehat{q}_i > q_i^*$ again.

Similar to the monopoly case, we can expect improved consumer surplus as a result of the increased production quantities. Thus, the possibility exists that subsequent insider trading also improves consumer welfare in a duopoly market.

Corollary 2.1. *In a Cournot product market and subsequent insider trading where the managers only trade in their own firms' shares, manager's ex-ante trading profit is*

$$E\left[\Pi_i\right] = \frac{m_a}{6}\sqrt{\frac{\Sigma_u\Sigma_a\Sigma_\theta}{2\Sigma_a + \Sigma_\theta}} + \frac{1}{12\omega}\frac{\Sigma_u\Sigma_a\Sigma_\theta}{2\Sigma_a + \Sigma_\theta},$$

which decreases in the manager's stake in the firm ω and accounting precision $\frac{1}{\Sigma_\theta}$.

Proof. See appendix.

The sum of the two managers' expected trading profit in a Cournot product market is only a $\frac{1}{3}$ of the manager's trading profit in a monopoly market, indicating that product market competition reduces insider trading profits. In a duopoly setting, the accounting precision again reduces the manager's ex-ante trading profit.

Corollary 2.2. *In a Cournot product market and subsequent insider trading where the managers only trade in their own firms' shares, each firm's ex-ante expected profit is*

$$E\left[V_i\right] = \frac{1}{6\omega}\left(2\omega m_a + \sqrt{\frac{\Sigma_u\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}}\right)\left(m_a - \left(\frac{1}{3\omega}\left(2\omega m_a + \sqrt{\frac{\Sigma_u\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}}\right)\right)\right),$$

which increases in the manager's stake in the firm ω and accounting precision $\frac{1}{\Sigma_\theta}$.

Proof. See appendix.

Since q_i^* maximizes firm i's profit in the Cournot product market, and $\widehat{q}_i < q_i^*$, we know the expected firm profit when $q = \widehat{q}_i$ is strictly lower than when $q = q_i^*$. This can be easily verified by comparing the profit levels when insider trading is not allowed and when it is allowed. The amount of profit reduction is however smaller than in the monopoly case, relative to the firm profit, because the manager's expected gain from insider trading in duopoly case achieved through the quantity distortion is smaller. Further, we show that expected ex-ante firm value in the Cournot setting still increases in the manager's current stake in the firm and the accounting precision, both of which reduce the manager's incentives to distort the firm's quantity decision.

3.3 When managers trade in both their competitors' and own firms' stocks

Now we allow the managers to trade in both their rival firms' and own firms' stocks. This new assumption leads to duopolistic competition of the two managers both in the product market and in the financial market. The manager i still chooses production quantity $\widehat{q}_i$ so as to maximize his total payoff

$$E\left[\omega\widetilde{V}_i\left(\widehat{q}_i\right)\right] + E\left[\Pi_i\left(\widehat{q}_i\right)\right]. \tag{13}$$

He chooses his demand for his own firm i's share, d_{ii}, so as to maximize his trading profit in firm i's shares

$$E\left[\left(V_i - \widetilde{P}_i\left(\widetilde{D}_i\right)\right)d_{ii}|\widetilde{V}_i = V_i\right]; \tag{14}$$

and his demand for firm j's share, d_{ij}, so as to maximize his trading profit in firm j's shares

$$E\left[\left(E\left[V_j|V_i\right] - \widetilde{P}_j\left(\widetilde{D}_j\right)\right)d_{ij}|\widetilde{V}_i = V_i\right]. \tag{15}$$

The market maker for firm i's stock sets the market clearing price by setting

$$P_i(D_i) = E[V_i | D_i = d_{ii} + d_{ji} + u]. \quad (16)$$

Manager i's linear strategies are

$$d_{ii}(V_i) = \alpha_{ii} + \beta_{ii} V_i \quad (17)$$

and

$$d_{ij}(E[V_j|V_i]) = \alpha_{ij} + \beta_{ij} E[V_j|V_i], \quad (18)$$

Lastly, the market maker i's linear pricing rule is

$$P_i(d_{ii} + d_{ji} + u) = \mu_i + \lambda_i (d_{ii} + d_{ji} + u). \quad (19)$$

The product market demand is updated to $(a|s_i, s_j) \sim N\left(\frac{\Sigma_\theta m_a + \Sigma_a(s_i+s_j)}{2\Sigma_a+\Sigma_\theta}, \frac{\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}\right)$ after s_i and s_j are disclosed. Thus, firm i's value is $\widetilde{V}_i \sim N\left(\widehat{q}_i(E[a|s_i,s_j] - \widehat{q}_i - \widehat{q}_j), \widehat{q}_i^2 \frac{\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}\right)$.

Proposition 3. *In a Cournot product market with subsequent insider trading where the managers trade in both their rival firms' and own firms' shares, there exists a unique linear equilibrium characterizing the strategies of the manager i and the market maker i, where i, $j = 1, 2$, as follows:*

$$\alpha_{ii} = \alpha_{ji} = -\frac{\sqrt{\Sigma_u}}{\sqrt{\frac{\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}}}(E[a|s_i,s_j] - \widehat{q}_i - \widehat{q}_j), \ \beta_{ii} = \beta_{ji} = \frac{1}{\widehat{q}_i}\frac{\sqrt{\Sigma_u}}{\sqrt{\frac{\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}}},$$

$$\mu_i = \widehat{q}_i(E[a|s_i,s_j] - \widehat{q}_i - \widehat{q}_j), \ \lambda_i = \frac{\widehat{q}_i}{3}\frac{\sqrt{\frac{\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}}}{\sqrt{\Sigma_u}},$$

and

$$\widehat{q}_i = \widehat{q}_j = \frac{1}{3}E[a|s_i,s_j] + \frac{1}{9\omega}\sqrt{\frac{\Sigma_u\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}}.$$

Proof. See appendix.

Compared to Proposition 2, Proposition 3 reflects the change in the players' strategies as a result of the change in the financial market in addition to the change in the product market. We know firm i's production quantity is $q_i^* = \frac{1}{3}E[a|s_i,s_j]$ when insider trading is not allowed. Firm i's production quantity is $\widehat{q}_i = q_i^* + \frac{1}{6\omega}\sqrt{\frac{\Sigma_u\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}}$ when insider trading is allowed and the managers only trade in their own firms' stocks. Firm i's production quantity is $\widehat{q}_i = q_i^* + \frac{1}{9\omega}\sqrt{\frac{\Sigma_u\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}}$ when insider trading is allowed and the managers trade in both their own and rival firms' stocks. We see that the production quantity is lowest when insider trading is not allowed, and highest when insider trading is allowed and the managers only trade in their own firms' stocks.

Corollary 3.1. *In a Cournot product market with subsequent insider trading where the managers trade in both their rival firms' and own firms' shares,the manager's ex-ante trading profit is*

$$E[\Pi_i] = \frac{m_a}{9}\sqrt{\frac{\Sigma_u\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}} + \frac{1}{27\omega}\frac{\Sigma_u\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta},$$

which decreases in the manager's stake in the firm ω and accounting precision $\frac{1}{\Sigma_\theta}$.

Proof. See appendix.

Compared to the expected insider trading profit when managers only trade in their own firms' stocks, their trading profits are lower when they can trade in both firms' stocks. This result is consistent with Holden and Subrahmanyam (1992) in that competition in the financial market reduces insider trading profit. Interestingly, the reduced insider trading profit also reduces the manager's incentive to distort the firm's operating decisions. Thus, when managers trade in both their own and rival firms' stocks, the production quantities are lower, and the expected firm profits are higher, than when managers only trade in their own firms' stocks.

Corollary 3.2. *In a Cournot product market with subsequent insider trading where the managers trade in both their rival firms' and own firms' shares, the firms earn an ex-ante expected profit*

$$E\left[\widetilde{V}_i\right] = \frac{1}{9\omega}\left(3\omega m_a + \sqrt{\frac{\Sigma_u\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}}\right)\left(m_a - \left(\frac{2}{9\omega}\left(3\omega m_a + \sqrt{\frac{\Sigma_u\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}}\right)\right)\right),$$

which increases in the manager's stake in the firm ω and accounting precision $\frac{1}{\Sigma_\theta}$.

Proof. See appendix.

Since the production quantity here is higher than the profit-maximizing level q_i^* when insider trading is forbidden, but lower than when the managers can only trade in their own firms' shares, the resulting firm profit level must be between the two cases as well. Therefore, there is less deviation from optimal operating decision when the managers can trade freely in both firms' stocks in the financial market.

3.4 When managers trade only in the rival's stock (substitute trading)

We also examine a third scenario, in which the managers trade their rival firm's shares only. That is, we let $d_{ii} = 0$. When insiders are forbidden from trading their own firms' shares, they can engage in "substitutes for insider trading," which involve trading shares of firms that are related with the firm that the insider has information about (Ayres and Bankman, 2001). For example, instead of trading his own firm's shares, the insider could trade shares of his firm's suppliers, customers, competitors, etc.. In fact, "substitute trading" could happen whenever an insider trades in the stocks of a firm whose realized value is correlated with his own firm's (Huang, 2006).

In our setting, since the two firms are symmetric, the manager of firm i is informationally an insider of firm j. However, he does not have any control over firm j's operations, as long as there is no collusive agreement between the two firms. Therefore, the insider trading part of the game is similar to the scenario of manager i trading only firm i's shares, but the production part of the game is different.

The manager chooses d_{ij}, his demand for firm j's share, to maximize his insider trading gain

$$E\left[\left(E\left[V_j|V_i\right]-\widetilde{P}_j\left(\widetilde{D}_j\right)\right)d_{ij}|\widetilde{V}_i=V_i\right]. \tag{20}$$

The market maker chooses P_j, the market clearing price for firm j's stock, by setting

$$P_j\left(D_j\right)=E\left[V_j|D_j=d_{ij}+u\right]. \tag{21}$$

Manager i's linear strategy is

$$d_{ij}\left(E\left[V_j|V_i\right]\right)=\alpha_{ij}+\beta_{ij}E\left[V_j|V_i\right], \tag{22}$$

and the market maker j's pricing rule is

$$P_j\left(d_j+u\right)=\mu_j+\lambda_j\left(d_{ij}+u\right). \tag{23}$$

Proposition 4. *In a Cournot product market with subsequent insider trading where the managers trade only their rival firms' shares, there exists a unique linear equilibrium characterizing the strategies of the manager i and the market maker j, where $i,\ j=1,2$, as follows:*

$$\alpha_{ij}=-\frac{\sqrt{\Sigma_u}}{\sqrt{\frac{\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}}}\left(E\left[a|s_i,s_j\right]-\widehat{q}_i-\widehat{q}_j\right),\ \beta_{ij}=\frac{\sqrt{\Sigma_u}}{\widehat{q}_j\sqrt{\frac{\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}}},$$
$$\mu_j=\widehat{q}_j\left(E\left[a|s_i,s_j\right]-\widehat{q}_i-\widehat{q}_j\right),\ \lambda_j=\frac{\widehat{q}_j}{2\sqrt{\Sigma_u}}\sqrt{\frac{\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}},$$

and

$$\widehat{q}_i=\widehat{q}_j=\frac{1}{3}E\left[a|s_i,s_j\right].$$

Proof. See appendix.

Note that the production quantity here is the same as q_i^*, when insider trading is not allowed. There is no distortion in the firms' operating decisions and their profits remain at the highest level. This is because the managers cannot control their rival firms' production decisions, and distorting their own firms' production quantities would not affect their expected insider trading gain.

Corollary 4.1. *In a Cournot product market with subsequent insider trading where the managers trade only in their rival firms' shares, the manager's ex-ante trading profit is*

$$E\left[\Pi_i\right]=\frac{m_a}{6}\sqrt{\frac{\Sigma_u\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}},$$

which decreases in the accounting precision $\frac{1}{\Sigma_\theta}$, but is not affected the manager's stake in the firm ω_i. The firms earn an ex-ante expected profit

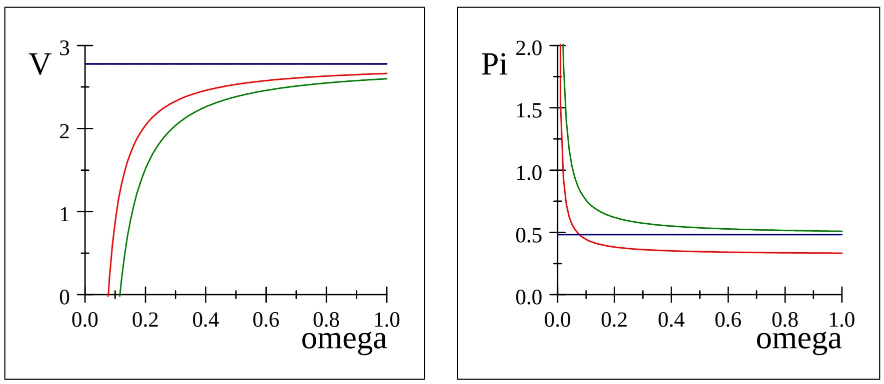
$$E\left[\widetilde{V}_i\right]=\frac{m_a^2}{9},$$

which is not affected by the manager's stake in the firm ω_i, nor by the accounting precision $\frac{1}{\Sigma_\theta}$.

Proof. See appendix.

In the case of substitute trading, the firm profit is the same as when insider trading is not allowed, while the managers are still able to earn some insider trading benefits. The expected ex-ante insider trading profit is strictly lower than when the managers can only trade in their own firms' stocks. This is because the managers cannot manipulate production quantities to increase his trading gain. Further, the insider trading benefits $E[\Pi_i]$ still decreases in the precision of accounting signal $\frac{1}{\Sigma_\theta}$, but is not affected by his stake in the firm, ω_i. The firms' expected profit $E\left[\widetilde{V}_i\right]$, is affected by neither $\frac{1}{\Sigma_\theta}$ nor ω_i.

We then compare the results of the four different scenarios, as illustrated in Figure 2.



Black: without insider trading; Green: trading in own firm's stock only;

Red: trading in both firms' stocks; Blue: trading in rival's stock only

Figure 2: Firm value and insider trading profit

in different insider trading scenarios.

In summary, comparing the expected firm values in the different insider trading scenarios, we find the firm value is lowest when the managers trade in only their own firms' stocks, and highest when insider trading is not possible or when the manager can only trade in their rivals' shares. The expected ex-ante firm value when insider trading is allowed and the managers trade in both their own and rival firms' stocks is ranked in the middle. On the other hand, the ex-ante expected insider trading profit is highest when the manager can only trade in his own firm's stocks, since he can has no competition as an insider in the financial market, and he can manipulate production quantity to further increase his personal benefits. However, the expected insider trading gains when the managers can trade in both firms' shares and when they can only trade in their rivals' shares are less straightforward. When the manager's stake in the firm is high, his trading gains are likely to be higher when he can only trade in the rival's stocks than when he can trade in both firms, because his incentive to manipulate the operations is lower.

Another observation we make is related to the consumer surplus. Since it unambiguously increases in the production output, consumer surplus is the highest when the managers can trade in their own firms' shares, and lowest when the managers can only trade in their rivals' shares, or when insider trading is not allowed at all. It is thus important for regulators to consider all the total social welfare when setting rules on insider trading.

4 Endogenizing manager's ownership through contracting

In the previous sections of the paper, we assumed that the manager's stake in the firm, ω, is exogenously given. A natural question that may arise is whether ω can be determined through contracting prior to the manager's operating decisions and trading. In the following discussion, we explore the possibility of ω being endogenous.

4.1 One-firm setting

We first examine the single-firm setting. Suppose the board of directors of the firm grants the manager a linear compensation contract of the form $S = \alpha + \omega V$, with α being the fixed salary, and ω being the manager's equity stake in the firm value. When granting the compensation contract, the board aims to maximize the firm value V net of the compensation paid to the manager. Similar to Baiman and Verrecchia (1995, 1996), we assume the board and the manager himself anticipate that the manager will engage in insider trading, and his ex-ante expected insider trading gain $E[\Pi]$ is part of his total payoff. Although $E[\Pi]$ is not a formal component of the manager's compensation, both the board and the manager are fully aware of this side benefit. We normalize the manager's reservation utility to zero. Both the board and the manager are risk neutral.

At time 0, when the compensation contract is being offered, the board maximizes the expected firm value net of the manager's pay

$$\max_{\alpha,\omega} E\left[V - (\alpha + \omega V)\right], \tag{24}$$

subject to the manager's individual participation constraint

$$E[\Pi] + \alpha + \omega E[V] \geq 0. \tag{25}$$

Given the manager's zero reservation utility, the binding participation constraint implies that his explicit pay and implicit benefits through future insider trading together sum up to zero. That is, $-\alpha = E[\Pi] + \omega E[V]$. By plugging the participation constraint into the board's objective function, we have

$$\max_{\omega} E[V] + E[\Pi]. \tag{26}$$

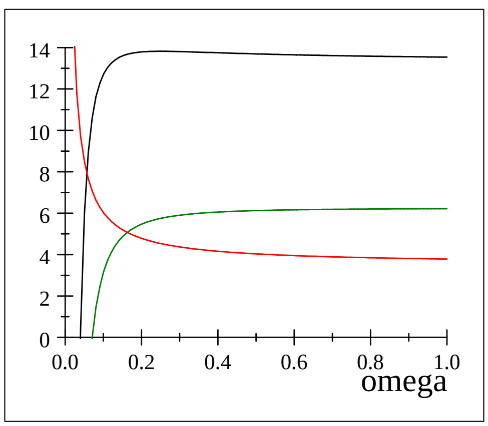
The rest of the game follows exactly the same time line as the basic model. The manager then receives a signal about the market demand, and makes the production quantity decision for the firm, before he trades in the firm's shares. We apply the same backward induction to derive the optimal ω, by first computing the manager's expected insider trading profits *à* la Kyle (1985), then the production quantity he chooses to maximize the sum of his insider trading gain and equity stake, and finally the optimal equity stake the board grants.

Proposition 5. *When the board of directors offers a linear contract in the form* $S = \alpha + \omega V$ *to the manager with subsequent insider trading opportunity in a monopoly product market, there is a unique interior solution for* ω^**, the optimal portion of stock granted.*

Proof. See appendix.

Observing the board's objective function, we see that it includes two parts: the expected firm value and the expected insider trading gain for the manager. The expected insider trading gain here equals the implicit benefits the manager obtains from future insider trading. The more benefits the manager can expect from insider trading, the less the board has to pay him through explicit compensation. Since the expected firm value $E[V]$ increases in ω and the expected insider trading gain $E[\Pi]$ decreases in ω, the board must choose the optimal ω by trading off the improvement in firm value with more explicit compensation she has to pay the manager.

Figure 3 illustrates how a unique ω^* can be obtained through a numerical example. We can see that $E[V]$ increases in ω and $E[\Pi]$ decreases in ω. However, because $E[V]$ increases less than $E[\Pi]$ decreases in ω, the board's objective function $E[V] + E[\Pi]$ has one unique peak of maximization in ω within the reasonable range of $[0, 1]$.



Green: firm value; Red: expected insider trading profits;

Black: firm value plus trading profits

Figure 3: Contracting in a single-firm setting.

4.2 Two-firm setting

In the two-firm setting, we first consider when the managers can only trade in their own firms' stocks. We still assume the two firms are identical and play symmetric strategies. Firm i's board of directors offers their manager a linear compensation contract in the form $S_i = \alpha_i + \omega_i V_i$ so as to maximize the expected firm value net of the manager's pay

$$\max_{\alpha_i,\omega_i} E\left[V_i - (\alpha_i + \omega_i V_i)\right]. \tag{27}$$

Manager i's individual rationality constraint is

$$E\left[\Pi_i\right] + \alpha_i + \omega_i E\left[V_i\right] \geq 0. \tag{28}$$

Substituting the manager's binding participation constraint into the objective function of firm i's , we have

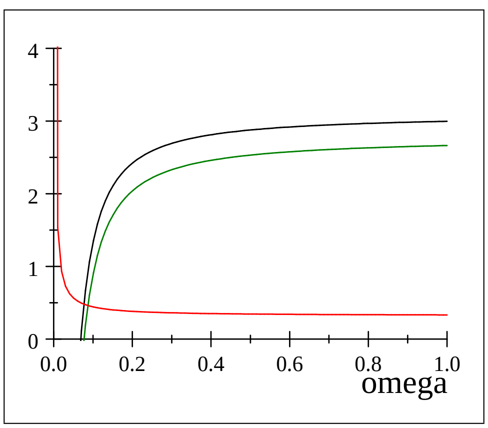
$$\max_{\omega_i} E\left[V_i\right] + E\left[\Pi_i\right]. \tag{29}$$

The rest of the game proceeds the same way as the two-firm setting when the managers only trade in their own firms' stocks.

Proposition 6. *When the board of directors of firm i offers a linear contract in the form $S_i = \alpha_i + \omega_i V_i$ to the manager with subsequent insider trading opportunity in a duopoly product market, the optimal portion of stock granted is a corner solution with $\omega_i^* = 1$.*

Proof. See appendix.

Again the board must choose the optimal ω_i by trading off the increase in firm value with the decrease in the expected insider trading gain, which equals the implicit benefits the manager obtains. In a two-firm setting, only a corner solution exists for the contract because the increase in firm value dominates the decrease in insider trading gain within the reasonable range of ω. Figure 4 illustrates the curvature of the board's objective function $[V] + E[\Pi]$ in ω through a numerical example. We can clearly see that it does not have a peak for the range $\omega \in [0, 1]$.



Green: firm value; Red: expected insider trading profits;

Black: firm value plus trading profits

Figure 4: Contracting in a two-firm setting.

The results are qualitatively similar when we consider other trading scenarios such as when managers can trade in both firms' shares, and when they can trade only in rival firms' shares. Thus, in the two-firm setting, the best solution for the board is to sell the firm to the manager before the production and insider trading activities even begin. However, the board may decide to not sell the whole firm to the manager due to other concerns that are not included in the model. For example, the manager may be risk averse. Or the firm profit is a function of the manager's personal effort. We do not consider these factors in this study.

5 Conclusions

In this paper, we intend to identify and evaluate a previously overlooked consequence of insider trading: real activities manipulation through purposeful overproduction. Specifically, we study insider trading in a setting where the manager of the firm also makes operating decisions in anticipation of subsequent insider trading opportunities. The effect of operating decisions on the variability of future firm value is the channel through which operating decisions also influence subsequent insider trading.

We find the production quantity with subsequent insider trading is strictly higher than quantity absent insider trading, leading to lower expected firm value but potentially higher consumer surplus. We also find that the competition among insiders in the financial market drives down the expected insider trading profits and results in less distorted production decisions, suggesting a substitute relation between product market competition and financial market competition.

Our results have some interesting policy implications. First, allowing insider trading in our setting hurts shareholder interests, but benefits the consumers. Second, the product market and the financial market are interrelated. When one market is being regulated, the other market will be affected as well. For example, restricting some insiders from trading in a firm's stock softens the competition in the financial market and leads to higher expected insider trading profits, but intensifies the competition in the product market by giving the managers incentive to overproduce.

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Appendix

A Proof of Proposition 1:

We use backward induction to find the solution to the problem.

In the second stage, we know both the manager and the market maker use linear strategies. That is, $d\left(\widetilde{V}\right)=\alpha+\beta\widetilde{V}$ and $P\left(\widetilde{d}+\widetilde{u}\right)=\mu+\lambda\left(\widetilde{d}+\widetilde{u}\right)$. The manager determines his demand d for the firm's shares so as to maximize his trading profit $E\left[\left(\widetilde{V}-\mu-\lambda\left(\widetilde{d}+\widetilde{u}\right)\right)d|\widetilde{V}=V\right]$, which equals $(V-\mu-\lambda d)\,d$.

Taking the first order condition w.r.t d and setting it equal to zero, we get $d=\frac{-\mu}{2\lambda}+\frac{1}{2\lambda}V$. Clearly, d is a linear function of V with $\alpha=\frac{-\mu}{2\lambda}$ and $\beta=\frac{1}{2\lambda}$.Based on s, we know that the market demand is $(a|s)\sim N\left(\frac{\Sigma_a s+\Sigma_\theta m_a}{\Sigma_a+\Sigma_\theta},\frac{\Sigma_a\Sigma_\theta}{\Sigma_a+\Sigma_\theta}\right)$. The corresponding final firm value is thus $\widetilde{V}\sim N\left(\widehat{q}\left(E\left[a|s\right]-\widehat{q}\right),\widehat{q}^2\frac{\Sigma_a\Sigma_\theta}{\Sigma_a+\Sigma_\theta}\right)$. Since $\widetilde{D}=\alpha+\beta\left(\widetilde{V}+\widetilde{u}\right)$, we know $\widetilde{D}$ is normally distributed with $\widetilde{D}\sim N\left(\alpha+\beta\widehat{q}\left(E\left[a|s\right]-\widehat{q}\right),\beta^2\widehat{q}^2\frac{\Sigma_a\Sigma_\theta}{\Sigma_a+\Sigma_\theta}+\Sigma_u\right)$. The market maker's market clearing condition is

$$p\left(D\right)=E\left[\widetilde{V}|\alpha+\beta\widetilde{V}+u\right]=\mu+\lambda\left(d+u\right), \tag{30}$$

indicating $\widetilde{D}$ and $\widetilde{V}$ have a var-cov matrix

$$\begin{bmatrix} \widehat{q}^2\frac{\Sigma_a\Sigma_\theta}{\Sigma_a+\Sigma_\theta} & \beta\widehat{q}^2\frac{\Sigma_a\Sigma_\theta}{\Sigma_a+\Sigma_\theta} \\ \beta\widehat{q}^2\frac{\Sigma_a\Sigma_\theta}{\Sigma_a+\Sigma_\theta} & \beta^2\widehat{q}^2\frac{\Sigma_a\Sigma_\theta}{\Sigma_a+\Sigma_\theta}+\Sigma_u \end{bmatrix}.$$

The market maker draws inference from $\widetilde{D}$ and updates her belief about $\widetilde{V}$ by setting $\lambda=\frac{\beta\widehat{q}^2\frac{\Sigma_a\Sigma_\theta}{\Sigma_a+\Sigma_\theta}}{\beta^2\widehat{q}^2\Sigma_a+\Sigma_u}$, and $\mu=\widehat{q}\left(E\left[a|s\right]-\widehat{q}\right)-\frac{\beta\widehat{q}^2\frac{\Sigma_a\Sigma_\theta}{\Sigma_a+\Sigma_\theta}}{\beta^2\widehat{q}^2\frac{\Sigma_a\Sigma_\theta}{\Sigma_a+\Sigma_\theta}+\Sigma_u}\left(\alpha+\beta\widehat{q}\left(E\left[a|s\right]-\widehat{q}\right)\right)$. Solving for the unknowns, we have

$$\begin{aligned} \alpha &= -\frac{\sqrt{\Sigma_u}}{\sqrt{\frac{\Sigma_a\Sigma_\theta}{\Sigma_a+\Sigma_\theta}}}\left(E\left[a|s\right]-\widehat{q}\right),\ \beta=\frac{\sqrt{\Sigma_u}}{\widehat{q}\sqrt{\frac{\Sigma_a\Sigma_\theta}{\Sigma_a+\Sigma_\theta}}}, \\ \mu &= \widehat{q}\left(E\left[a|s\right]-\widehat{q}\right),\ \lambda=\frac{1}{2}\frac{\widehat{q}}{\Sigma_u}\sqrt{\frac{\Sigma_u\Sigma_a\Sigma_\theta}{\Sigma_a+\Sigma_\theta}}. \end{aligned}$$

The price for the firm's stock is therefore

$$p(D) = \frac{1}{2}\widehat{q}\left((E[a|s] - \widehat{q}) + (\widetilde{a} - \widehat{q}) + \frac{1}{\Sigma_u}\sqrt{\frac{\Sigma_u \Sigma_a \Sigma_\theta}{\Sigma_a + \Sigma_\theta}}\widetilde{u} \right). \tag{31}$$

The manager's demand for the firm's stock is

$$d = -\frac{\sqrt{\Sigma_u}}{\sqrt{\frac{\Sigma_a \Sigma_\theta}{\Sigma_a + \Sigma_\theta}}} (E[a|s] - \widehat{q}) + \frac{\sqrt{\Sigma_u}}{\sqrt{\frac{\Sigma_a \Sigma_\theta}{\Sigma_a + \Sigma_\theta}}} (\widetilde{a} - \widehat{q}). \tag{32}$$

The manager's trading profit is therefore

$$E\left[\left(\widetilde{V} - p\right) d\right] = E\left[\frac{\sqrt{\Sigma_u}}{2\widehat{q}\sqrt{\frac{\Sigma_a \Sigma_\theta}{\Sigma_a + \Sigma_\theta}}} \left((\widehat{q}(\widetilde{a} - \widehat{q})) - \widehat{q}(a - \widehat{q}) \right)^2 \right]. \tag{33}$$

Conditional on not yet knowing $\widetilde{a}$, the above trading profit is $\frac{\widehat{q}}{2}\sqrt{\frac{\Sigma_u \Sigma_a \Sigma_\theta}{\Sigma_a + \Sigma_\theta}}$.

Now we consider the first stage of the game, when the manager makes the quantity decision for the firm. The manager's objective function is a combination of trading profits Π and firm value V. The manager maximizes

$$E[\Pi] + \omega[V] = \omega\widehat{q}(E[a|s] - \widehat{q}) + \frac{\widehat{q}}{2}\sqrt{\frac{\Sigma_u \Sigma_a \Sigma_\theta}{\Sigma_a + \Sigma_\theta}} \tag{34}$$

Taking the first order condition w.r.t. $\widehat{q}$ and setting it equal to zero, we have $\widehat{q} = \frac{2\omega E[a|s] + \sqrt{\frac{\Sigma_u \Sigma_a \Sigma_\theta}{\Sigma_a + \Sigma_\theta}}}{4\omega}$.

B Proof of Corollary 1.1:

From the proof of Proposition 1, we know the manager's trading profit is

$$\begin{aligned} E\left[\left(\widetilde{V} - P\right) d\right] &= \frac{E[\widehat{q}]}{2}\sqrt{\frac{\Sigma_u \Sigma_a \Sigma_\theta}{\Sigma_a + \Sigma_\theta}} \\ &= E\left[\frac{\Sigma_a \widetilde{s} + \Sigma_\theta m_a}{\Sigma_a + \Sigma_\theta}\right]\sqrt{\frac{\Sigma_u \Sigma_a \Sigma_\theta}{\Sigma_a + \Sigma_\theta}} + \frac{1}{2\omega}\frac{\Sigma_u \Sigma_a \Sigma_\theta}{\Sigma_a + \Sigma_\theta}. \end{aligned} \tag{35}$$

Since the $E[\widetilde{s}] = m_a$, we know the $E\left[\frac{\Sigma_a \widetilde{s} + \Sigma_\theta m_a}{\Sigma_a + \Sigma_\theta}\right] = m_a$. Thus the above simplifies to $E[\Pi] = m_a\sqrt{\frac{\Sigma_u \Sigma_a \Sigma_\theta}{\Sigma_a + \Sigma_\theta}} + \frac{1}{2\omega}\frac{\Sigma_u \Sigma_a \Sigma_\theta}{\Sigma_a + \Sigma_\theta}$. Taking the first order derivative of $E[\Pi]$ with regard to Σ_θ, we have $\frac{1}{2\omega}\frac{\Sigma_a}{\Sigma_\theta(\Sigma_a + \Sigma_\theta)}\left(\sqrt{\Sigma_a \Sigma_u \frac{\Sigma_\theta}{\Sigma_a + \Sigma_\theta}} + \omega m_a\right)\sqrt{\Sigma_a \Sigma_u \frac{\Sigma_\theta}{\Sigma_a + \Sigma_\theta}} > 0$. Thus $E[\Pi]$ increases in Σ_θ, or decreases in $\frac{1}{\Sigma_\theta}$.

C Proof of Corollary 1.2:

When insider trading is allowed, the expected firm profit is

$$\begin{aligned} E[V] &= E\left(E[\widehat{q}]\left(\widetilde{a}-E[\widehat{q}]\right)\right) \\ &= \frac{1}{16\omega^2}\left(4\omega^2\left(E\left[\frac{\Sigma_a\widetilde{s}+\Sigma_\theta m_a}{\Sigma_a+\Sigma_\theta}\right]\right)^2-\frac{\Sigma_u\Sigma_a\Sigma_\theta}{\Sigma_a+\Sigma_\theta}\right) \\ &= \frac{1}{16\omega^2}\left(4\omega^2 m_a^2-\frac{\Sigma_u\Sigma_a\Sigma_\theta}{\Sigma_a+\Sigma_\theta}\right). \end{aligned} \tag{36}$$

Examining the relation between expected firm profit and the manager's current stake in the firm, we have $\frac{\partial}{\partial\omega}\left(E[V]\right)=\frac{1}{8\omega^3}\sqrt{\frac{\Sigma_u\Sigma_a\Sigma_\theta}{\Sigma_a+\Sigma_\theta}}>0$, indicating $E[V]$ increases in ω. Examining the relation between expected firm profit and Σ_θ, we have $\frac{\partial}{\partial\Sigma_\theta}\left(E[V]\right)=-\frac{1}{16\omega^2}\Sigma_a^2\frac{\Sigma_u}{(\Sigma_a+\Sigma_\theta)^2}<0$, indicating $E[V]$ decreases in Σ_θ, or increases in accounting precision $\frac{1}{\Sigma_\theta}$.

D Proof of Proposition 2:

In the second stage, manager 1 and the market maker 1 use linear strategies $d_1(V_1)=\alpha_1+\beta_1\widetilde{V}_1$ and $P_1\left(\widetilde{d}_1+\widetilde{u}\right)=\mu_1+\lambda_1\left(\widetilde{d}_1+\widetilde{u}\right)$. Manager i determines d_i so as to maximize his trading profit $E\left[\left(\widetilde{V}_1-\mu_1-\lambda_1\left(\widetilde{d}_1+\widetilde{u}\right)\right)d_1|\widetilde{V}_1=V_1\right]=\left(V_1-\mu_1-\lambda_1 d_1\right)d_1$. Taking the first order condition w.r.t d_1 and setting it equal to zero, we get $\alpha_1=\frac{-\mu_1}{2\lambda_1}$ and $\beta_1=\frac{1}{2\lambda_1}$.

Based on s_1 and s_2, the updated market demand is $(a|s_1,s_2)\sim N\left(\frac{\Sigma_\theta m_a+\Sigma_a(s_1+s_2)}{2\Sigma_a+\Sigma_\theta},\frac{\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}\right)$. The corresponding final firm value is thus $\widetilde{V}_1\sim N\left(\widehat{q}_1\left(E[a|s_1,s_2]-\widehat{q}_1-\widehat{q}_2\right),\widehat{q}_1^2\frac{\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}\right)$. Since $\widetilde{D}_1=\alpha_1+\beta_1\left(\widetilde{V}_1+\widetilde{u}\right)$, we have $\widetilde{D}_1\sim N\left(\alpha_1+\beta_1\widehat{q}_1\left(E[a|s_1,s_2]-\widehat{q}_1-\widehat{q}_2\right),\beta_1^2\widehat{q}_1^2\frac{\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}+\Sigma_u\right)$. We also know that $\widetilde{V}_1$ and $\widetilde{D}_1$ are bivariate normal with

$$\begin{pmatrix}\widetilde{V}_1\\ \widetilde{D}_1\end{pmatrix}\sim N_2\left[\begin{array}{c}\widehat{q}_1\left(E[a|s_1,s_2]-\widehat{q}_1-\widehat{q}_2\right)\\ \alpha_1+\beta_1\widehat{q}_1\left(E[a|s_1,s_2]-\widehat{q}_1-\widehat{q}_2\right)\end{array},\begin{array}{cc}\widehat{q}_1^2\frac{\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta} & \beta_1\widehat{q}_1^2\frac{\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}\\ \beta_1\widehat{q}_1^2\frac{\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta} & \beta_1^2\widehat{q}_1^2\frac{\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}+\Sigma_u\end{array}\right].$$

Market maker 1 thus decides that $\lambda_1=\frac{\beta_1\widehat{q}_1^2\frac{\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}}{\beta_1^2\widehat{q}_1^2\frac{\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}+\Sigma_u}$ and $\mu_1=\widehat{q}_1\left(E[a|s_1,s_2]-\widehat{q}_1-\widehat{q}_2\right)$ $-\frac{\beta_1\widehat{q}_1^2\frac{\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}}{\beta_1^2\widehat{q}_1^2\frac{\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}+\Sigma_u}\left(\alpha_1+\beta_1\widehat{q}_1\left(E[a|s_1,s_2]-\widehat{q}_1-\widehat{q}_2\right)\right)$. Solving for the unknowns, we have

$$\begin{aligned} \alpha_1 &= -\frac{\sqrt{\Sigma_u}}{\sqrt{\frac{\Sigma_a\Sigma_\theta}{\Sigma_a+\Sigma_\theta}}}\left(E[a|s_1,s_2]-\widehat{q}_1-\widehat{q}_2\right),\ \beta_1=\frac{\sqrt{\Sigma_u}}{\widehat{q}_1\sqrt{\frac{\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}}} \\ \mu_1 &= \widehat{q}_1\left(E[a|s_1,s_2]-\widehat{q}_1-\widehat{q}_2\right),\ \lambda_1=\frac{1}{2}\frac{\widehat{q}_1}{\Sigma_u}\sqrt{\frac{\Sigma_u\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}}. \end{aligned}$$

The price for firm 1's share is therefore

$$P_1(D_1)=\frac{1}{2}\widehat{q}_1\left(E[a|s_1,s_2]-\widehat{q}_1-\widehat{q}_2\right)+\frac{1}{2}\widehat{q}_1\left(\widetilde{a}-\widehat{q}_1-\widehat{q}_2\right)+\frac{1}{2\Sigma_u}\widehat{q}_1\sqrt{\frac{\Sigma_u\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}}\widetilde{u}, \tag{37}$$

and manager 1's trading profit conditional on not knowing V_1 is $E\left[\left(\widetilde{V}_1-\widetilde{P}_1\right)d_1\right]=\frac{\widehat{q}_1}{2}\sqrt{\frac{\Sigma_u\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}}$.

In the first stage, manager 1 decides his production quantity $\widehat{q}_1$ so as to maximize his total payoff $\omega E\left[\widetilde{V}_1\right]+E\left[\Pi_1\right]=\omega\widehat{q}_1\left(E\left[a|s_1,s_2\right]-\widehat{q}_1-\widehat{q}_2\right)+\frac{\widehat{q}_1}{2}\sqrt{\frac{\Sigma_u\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}}$. Taking the first order condition with regard to $\widehat{q}_1$ and setting it equal to zero, we have $\widehat{q}_1=\frac{2\omega(E[a|s_1,s_2]-\widehat{q}_2)+\sqrt{\frac{\Sigma_u\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}}}{4\omega}$. The problem facing manager 2 and market maker 2 is identical. Applying symmetry, we have $\widehat{q}_1=\widehat{q}_2=\frac{1}{6\omega}\left(2\omega E\left[a|s_1,s_2\right]+\sqrt{\frac{\Sigma_u\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}}\right)$.

E Proof of Corollary 2.1:

Substituting the solutions from Proposition 2, we know the manager i's expected trading profit $E\left[\Pi_i\right]$ is

$$\begin{aligned}E\left[\left(\widetilde{V}_i-\widetilde{P}_i\right)d_i\right]&=\frac{E\left[\widehat{q}_i\right]}{2}\sqrt{\frac{\Sigma_u\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}}\\ &=\frac{1}{12\omega}\frac{\Sigma_u\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}+\frac{1}{6}E\left[\frac{\Sigma_\theta m_a+\Sigma_a\left(\widetilde{s}_i+\widetilde{s}_j\right)}{2\Sigma_a+\Sigma_\theta}\right]\sqrt{\frac{\Sigma_u\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}}\\ &=\frac{1}{12\omega}\frac{\Sigma_u\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}+\frac{m_a}{6}\sqrt{\frac{\Sigma_u\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}}. \qquad (38)\end{aligned}$$

Computing $\frac{\partial}{\partial\Sigma_\theta}E\left[\Pi_i\right]$, we have $\frac{1}{6\omega}\frac{\Sigma_a}{\Sigma_\theta}\frac{\omega m_a+\sqrt{\Sigma_a\Sigma_u\frac{\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}}}{2\Sigma_a+\Sigma_\theta}\sqrt{\Sigma_a\Sigma_u\frac{\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}}>0$.

F Proof of Corollary 2.2:

Given the solutions in Proposition 2, the expected firm value when insider trading is allowed is

$$\begin{aligned}E\left[\widetilde{V}_i\right]&=E\left[E\left[\widehat{q}_i\right]\left(\widetilde{a}-E\left[\widehat{q}_i\right]-E\left[\widehat{q}_j\right]\right)\right]\\ &=\frac{1}{6\omega}\left(2\omega E\left[\frac{\Sigma_\theta m_a+\Sigma_a\left(\widetilde{s}_i+\widetilde{s}_j\right)}{2\Sigma_a+\Sigma_\theta}\right]+\sqrt{\frac{\Sigma_u\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}}\right)\\ &\quad\left(E\left[\frac{\Sigma_\theta m_a+\Sigma_a\left(\widetilde{s}_i+\widetilde{s}_j\right)}{2\Sigma_a+\Sigma_\theta}\right]-2\left(\frac{1}{6\omega}\left(2\omega E\left[\frac{\Sigma_\theta m_a+\Sigma_a\left(\widetilde{s}_i+\widetilde{s}_j\right)}{2\Sigma_a+\Sigma_\theta}\right]+\sqrt{\frac{\Sigma_u\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}}\right)\right)\right)\\ &=\frac{1}{6\omega}\left(2\omega m_a+\sqrt{\frac{\Sigma_u\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}}\right)\left(m_a-\left(\frac{1}{3\omega}\left(2\omega m_a+\sqrt{\frac{\Sigma_u\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}}\right)\right)\right). \qquad (39)\end{aligned}$$

Further, taking the first order derivative of $E\left[V_i\right]$ when insider trading is allowed, we have $\frac{2\Sigma_a\Sigma_u\Sigma_\theta+(2\omega\Sigma_a m_a+\omega\Sigma_\theta m_a)\sqrt{\Sigma_a\Sigma_u\frac{\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}}}{18\omega^3(2\Sigma_a+\Sigma_\theta)}>0$. Again, we see the expected firm value increases in the manager's stake in the firm. Taking the first order derivative of $E\left[\Pi_i\right]$ with regard to Σ_θ, we have $-\frac{1}{18\omega^2}\frac{\Sigma_a}{\Sigma_\theta}\frac{\omega m_a+2\sqrt{\Sigma_a\Sigma_u\frac{\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}}}{2\Sigma_a+\Sigma_\theta}\sqrt{\Sigma_a\Sigma_u\frac{\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}}<0$, implying the expected firm value increases in the accounting precision $\frac{1}{\Sigma_\theta}$.

G Proof of Proposition 3:

Let $d_{11}\left(\widetilde{V}_1\right)=\alpha_{11}+\beta_{11}\widetilde{V}_1$ be the demand manager 1 submits for firm 1's shares; and $d_{12}\left(\widetilde{V}_1\right)=\alpha_{12}+\beta_{12}\widetilde{V}_1$ be the demand manager 1 submits for firm 2's shares. Let $d_{22}\left(\widetilde{V}_2\right)=\alpha_{22}+\beta_{22}\widetilde{V}_2$ be the demand manager 2 submits for firm 2's shares, and $d_{21}\left(\widetilde{V}_2\right)=\alpha_{21}+\beta_{21}\widetilde{V}_2$ be the demand manager 2 submits for firm 1's shares. Market maker 1 sets the linear pricing strategy $p_1\left(\widetilde{d}_{11}+\widetilde{d}_{21}+\widetilde{u}_1\right)=\mu_1+\lambda_1\left(\widetilde{d}_{11}+\widetilde{d}_{21}+\widetilde{u}_1\right)$, and market maker 2 sets the strategy $p_2\left(\widetilde{d}_{22}+\widetilde{d}_{12}+\widetilde{u}_2\right)=\mu_2+\lambda_2\left(\widetilde{d}_{22}+\widetilde{d}_{12}+\widetilde{u}_2\right)$.

Manager 1 maximizes his trading profits from both firm 1's shares and firm 2's shares

$$E\left[\left(\widetilde{V}_1-\widetilde{p}_1\right)d_{11}|\widetilde{V}_1=V_1\right]+E\left[\left(E\left[\widetilde{V}_2\right]-\widetilde{p}_2\right)d_{12}|\widetilde{V}_1=V_1\right]. \tag{40}$$

Since the production quantities are public information, and both managers observe the realized common market demand $\widetilde{a}=a$, the two managers know each other's firm values perfectly. That is, manager 1's objective function is

$$\begin{aligned}
&\max_{d_{11},d_{12}} E\left[\left(\widetilde{V}_1-\widetilde{p}_1\right)d_{11}|\widetilde{V}_1=V_1\right]+E\left[\left(\widetilde{V}_2-\widetilde{p}_2\right)d_{12}|\widetilde{V}_2=V_2\right]\\
=\;&\left(V_1-\mu_1-\lambda_1\left(d_{11}+d_{21}\right)\right)d_{11}+\left(V_2-\mu_2-\lambda_2\left(d_{12}+d_{22}\right)\right)d_{12}
\end{aligned} \tag{41}$$

Taking the first order condition with regard to d_{11} and d_{12} we have $\widetilde{V}_1-\mu_1-2\lambda_1 d_{11}-\lambda_1 d_{21}=0$, and $\widetilde{V}_2-\mu_2-2\lambda_2 d_{12}-\lambda_2 d_{22}=0$.

Manager 2's problem is symmetric to manager 1's. Thus we know

$$\begin{aligned}
d_{11}&=-\frac{1}{2\lambda_1}\left(-\widetilde{V}_1+\mu_1+\lambda_1 d_{21}\right),\ d_{12}=-\frac{1}{2\lambda_2}\left(-\widetilde{V}_2+\mu_2+\lambda_2 d_{22}\right),\\
d_{22}&=-\frac{1}{2\lambda_2}\left(-\widetilde{V}_2+\mu_2+\lambda_2 d_{12}\right),\ d_{21}=-\frac{1}{2\lambda_1}\left(-\widetilde{V}_1+\mu_1+\lambda_1 d_{11}\right),
\end{aligned}$$

which is equivalent to

$$\begin{aligned}
\alpha_{11}&=\alpha_{21}=\frac{-\mu_1}{3\lambda_1},\ \beta_{11}=\beta_{21}=\frac{1}{3\lambda_1},\\
\alpha_{12}&=\alpha_{22}=\frac{-\mu_2}{3\lambda_2},\ \beta_{12}=\beta_{22}=\frac{1}{3\lambda_2}.
\end{aligned}$$

We know that market maker 1's strategy is

$$P_1\left(\widetilde{D}_1\right)=\mu_1+\lambda_1\left(\alpha_{11}+\beta_{11}\widetilde{V}_1+\alpha_{21}+\beta_{21}\widetilde{V}_2+\widetilde{u}_1\right). \tag{42}$$

Again $\widetilde{V}_1$ and $\widetilde{D}_1$ are bivariate normally distributed with means $\widehat{q}_1\left(E\left[a|s_1,s_2\right]-\widehat{q}_1-\widehat{q}_2\right)$ and $\alpha_{11}+\beta_{11}\widehat{q}_1\left(E\left[a|s_1,s_2\right]-\widehat{q}_1-\widehat{q}_2\right)+\alpha_{21}+\beta_{21}\widehat{q}_2\left(E\left[a|s_1,s_2\right]-\widehat{q}_1-\widehat{q}_2\right)$, respectively. Their var-cov matrix is

$$\begin{bmatrix}
\widehat{q}_1^2\frac{\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta} & \beta_{11}\widehat{q}_1^2\frac{\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}\\
\beta_{11}\widehat{q}_1^2\frac{\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta} & \left(\beta_{11}^2\widehat{q}_1^2+\beta_{21}^2\widehat{q}_2^2\right)\frac{\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}+\Sigma_u
\end{bmatrix}.$$

Thus, we have

$$\begin{aligned}\lambda_1 &= \frac{\beta_{11}\widehat{q}_1^2\frac{\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}}{\left(\beta_{11}^2\widehat{q}_1^2+\beta_{21}^2\widehat{q}_2^2\right)\frac{\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}+\Sigma_u},\ \mu_1 = E\left[\widetilde{V}_1\right]-\lambda_1 E\left[\widetilde{D}_1\right],\\ \lambda_2 &= \frac{\beta_{22}\widehat{q}_2^2\frac{\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}}{\left(\beta_{22}\widehat{q}_2^2+\beta_{12}^2\widehat{q}_1^2\right)\frac{\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}+\Sigma_u},\ \mu_2 = E\left[\widetilde{V}_2\right]-\lambda_2 E\left[\widetilde{D}_2\right].\end{aligned}$$

Solving for all the unknowns, we get

$$\begin{aligned}&\alpha_{11} = -\frac{1}{\sqrt{2\widehat{q}_1^2-\widehat{q}_2^2}}\frac{\sqrt{\Sigma_u}}{\sqrt{\frac{\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}}}\left(2\widehat{q}_1-\widehat{q}_2\right)\left(E\left[a|s_1,s_2\right]-\widehat{q}_1-\widehat{q}_2\right),\\ &\alpha_{12} = -\frac{1}{\sqrt{2\widehat{q}_2^2-\widehat{q}_1^2}}\frac{\sqrt{\Sigma_u}}{\sqrt{\frac{\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}}}\left(2\widehat{q}_1-\widehat{q}_1\right)\left(E\left[a|s_1,s_2\right]-\widehat{q}_2-\widehat{q}_1\right),\\ &\beta_{11} = \frac{1}{\sqrt{2\widehat{q}_1^2-\widehat{q}_2^2}}\frac{\sqrt{\Sigma_u}}{\frac{\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}},\ \beta_{12} = \frac{1}{\sqrt{2\widehat{q}_2^2-\widehat{q}_1^2}}\frac{\sqrt{\Sigma_u}}{\frac{\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}},\\ &\mu_1 = \left(2\widehat{q}_1-\widehat{q}_2\right)\left(E\left[a|s_1,s_2\right]-\widehat{q}_1-\widehat{q}_2\right),\lambda_1 = \frac{\sqrt{2\widehat{q}_1^2-\widehat{q}_2^2}}{3}\frac{\sqrt{\frac{\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}}}{\sqrt{\Sigma_u}}.\end{aligned}$$

For manager 2 and market maker 2, the solutions are symmetric. Substituting the solutions into manager 1's total trading profit $E\left[\left(V_1-\mu_1-\lambda_1\left(d_{11}+d_{21}\right)\right)d_{11}\right]+E\left[\left(V_2-\mu_2-\lambda_2\left(d_{12}+d_{22}\right)\right)d_{12}\right]$, conditional on manager 1 does not know the final value of a, we know his total expected trading profit is

$$\begin{aligned}&E\left[\frac{1}{3\sqrt{2\widehat{q}_1^2-\widehat{q}_2^2}}\frac{\sqrt{\Sigma_u}}{\sqrt{\frac{\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}}}\left(\widetilde{V}_1-\left(2V_1-V_2\right)\right)^2\right]+E\left[\frac{1}{3\sqrt{2\widehat{q}_2^2-\widehat{q1}^2}}\frac{\sqrt{\Sigma_u}}{\sqrt{\frac{\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}}}\left(\widetilde{V}_1-\left(2V_2-V_1\right)\right)^2\right]\\ =\ &\frac{\widehat{q}_1^2\sqrt{\frac{\Sigma_u\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}}}{3\sqrt{2\widehat{q}_1^2-\widehat{q}_2^2}}+\frac{\widehat{q}_2^2\sqrt{\frac{\Sigma_u\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}}}{3\sqrt{2\widehat{q}_2^2-\widehat{q}_1^2}}. \qquad (43)\end{aligned}$$

Manager 1 thus maximizes his total payoff by choosing quantity $\widehat{q}_1$:

$$\max_{\widehat{q}_1}\omega\left(\widehat{q}_1\left(E\left[a|s_1,s_2\right]-\widehat{q}_1-\widehat{q}_2\right)\right)+\frac{\widehat{q}_1^2\sqrt{\frac{\Sigma_u\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}}}{3\sqrt{2\widehat{q}_1^2-\widehat{q}_2^2}}+\frac{\widehat{q}_2^2\sqrt{\frac{\Sigma_u\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}}}{3\sqrt{2\widehat{q}_2^2-\widehat{q}_1^2}} \qquad (44)$$

Taking the first order condition with regard to $\widehat{q}_1$ and setting it equal to zero, we have

$$\omega\left(E\left[a|s_1,s_2\right]-2\widehat{q}_1-\widehat{q}_2\right)+\frac{1}{3}\sqrt{\frac{\Sigma_u\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}}\left(\frac{2\widehat{q}_1\left(\widehat{q}_1^2-\widehat{q}_2^2\right)}{\left(2\widehat{q}_1^2-\widehat{q}_2^2\right)^{\frac{3}{2}}}+\frac{\widehat{q}_1\widehat{q}_2^2}{\left(2\widehat{q}_2^2-\widehat{q}_1^2\right)^{\frac{3}{2}}}\right)=0. \qquad (45)$$

Manager 2's problem is symmetric. Applying symmetry and solving for $\widehat{q}_1=\widehat{q}_2$, we get $\widehat{q}_1=\widehat{q}_2=\frac{1}{9\omega}\left(3\omega E\left[a|s_1,s_2\right]+\sqrt{\frac{\Sigma_u\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}}\right)$.

H Proof of Corollary 3.1:

Substituting the solutions from Proposition 3, we know the manager i's expected trading profit $E[\Pi_i]$ is

$$\begin{aligned} E[\Pi_i] &= \frac{E[\widehat{q}]}{3}\sqrt{\frac{\Sigma_u\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}} \\ &= \frac{\Sigma_u}{27\omega}\frac{\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}+\frac{1}{9}E\left[\frac{\Sigma_\theta m_a+\Sigma_a(\widetilde{s}_i+\widetilde{s}_j)}{2\Sigma_a+\Sigma_\theta}\right]\sqrt{\frac{\Sigma_u\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}} \\ &= \frac{\Sigma_u}{27\omega}\frac{\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}+\frac{m_a}{9}\sqrt{\frac{\Sigma_u\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}} \end{aligned} \tag{46}$$

Computing $\frac{\partial}{\partial\Sigma_\theta}E[\Pi_i]$, we have $\frac{1}{9\omega}\frac{\Sigma_a}{\Sigma_\theta}\frac{\omega m_a+\sqrt{\Sigma_a\Sigma_u\frac{\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}}}{2\Sigma_a+\Sigma_\theta}\sqrt{\Sigma_a\Sigma_u\frac{\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}}>0$.

I Proof of Corollary 3.2:

The expected firm value when insider trading is allowed and the managers trade in both own and rival firms' stocks is

$$\begin{aligned} E\left[\widetilde{V}_i\right] &= E\left[E[\widehat{q}_i](\widetilde{a}-E[\widehat{q}_i]-E[\widehat{q}_j])\right] \\ &= \frac{1}{9\omega}\left(3\omega E\left[\frac{\Sigma_\theta m_a+\Sigma_a(\widetilde{s}_i+\widetilde{s}_j)}{2\Sigma_a+\Sigma_\theta}\right]+\sqrt{\frac{\Sigma_u\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}}\right) \\ &\quad \left(E\left[\frac{\Sigma_\theta m_a+\Sigma_a(\widetilde{s}_i+\widetilde{s}_j)}{2\Sigma_a+\Sigma_\theta}\right]-2\left(\frac{1}{9\omega}\left(3\omega E\left[\frac{\Sigma_\theta m_a+\Sigma_a(\widetilde{s}_i+\widetilde{s}_j)}{2\Sigma_a+\Sigma_\theta}\right]+\sqrt{\frac{\Sigma_u\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}}\right)\right)\right) \\ &= \frac{1}{9\omega}\left(3\omega m_a+\sqrt{\frac{\Sigma_u\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}}\right)\left(m_a-\left(\frac{2}{9\omega}\left(3\omega m_a+\sqrt{\frac{\Sigma_u\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}}\right)\right)\right). \end{aligned} \tag{47}$$

Taking the first order derivative of $E[V_i]$ w.r.t. ω_i, we have $\frac{\left(4\Sigma_a\Sigma_u\Sigma_\theta+(6\omega\Sigma_a+3\omega\Sigma_\theta)m_a\sqrt{\Sigma_a\Sigma_u\frac{\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}}\right)}{81\omega^3(2\Sigma_a+\Sigma_\theta)}$ >0. Again, we see the expected firm value increases in the manager's stake in the firm. Taking first order derivative of $E[V_i]$ with regard to Σ_θ, we have $-\frac{1}{81\omega^2}\frac{\Sigma_a}{\Sigma_\theta}\frac{3\omega m_a+4\sqrt{\Sigma_a\Sigma_u\frac{\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}}}{2\Sigma_a+\Sigma_\theta}\sqrt{\Sigma_a\Sigma_u\frac{\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}}$ <0, implying that $E[V_i]$ increases in accounting precision $\frac{1}{\Sigma_\theta}$.

J Proof of Proposition 4

Again, we use backward induction to find the solution.

In the second stage, manager 1 and the market maker 1 use linear strategies $d_1(V_2)=\alpha_1+\beta_1\widetilde{V}_2$ and $P_2\left(\widetilde{d}_1+\widetilde{u}\right)=\mu_2+\lambda_2\left(\widetilde{d}_1+\widetilde{u}\right)$. Manager 1 determines d_{12} by maximizing his trading profit

$$\begin{aligned} &\max_{d_{12}}E\left[\left(\widetilde{V}_2-\mu_2-\lambda_2\left(\widetilde{d}_{12}+\widetilde{u}\right)\right)d_{12}|\widetilde{V}_2=V_2\right] \\ =\ &(V_2-\mu_2-\lambda_2 d_{12})\,d_{12}. \end{aligned} \tag{48}$$

Taking the first order condition w.r.t d_{12} and setting it equal to zero, we get $\alpha_{12} = \frac{-\mu_2}{2\lambda_2}$ and $\beta_{12} = \frac{1}{2\lambda_2}$.

Based on s_1 and s_2, the updated market demand is $(a|s_1,s_2) \sim N\left(E[a|s_1,s_2], \frac{\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}\right)$. The corresponding final firm value is thus $\widetilde{V}_2 \sim N\left(\widehat{q}_2\left(E[a|s_1,s_2]-\widehat{q}_1-\widehat{q}_2\right), \widehat{q}_2^2\frac{\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}\right)$. Since $\widetilde{D}_1 = \alpha_{12}+\beta_{12}\widetilde{V}_2+\widetilde{u}$, we know $\widetilde{D}_1 \sim N\left(\alpha_{12}+\beta_{12}\widehat{q}_2\left(E[a|s_1,s_2]-\widehat{q}_1-\widehat{q}_2\right),\ \beta_{12}^2\widehat{q}_2^2\frac{\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}+\Sigma_u\right)$. We also know that $\widetilde{V}_2$ and $\widetilde{D}_1$ are bivariate normal with

$$\begin{pmatrix}\widetilde{V}_2\\ \widetilde{D}_1\end{pmatrix} \sim N_2\left[\begin{array}{c}\widehat{q}_2\left(E[a|s_1,s_2]-\widehat{q}_1-\widehat{q}_2\right)\\ \alpha_{12}+\beta_{12}\widehat{q}_2\left(E[a|s_1,s_2]-\widehat{q}_1-\widehat{q}_2\right)\end{array}, \begin{array}{cc}\widehat{q}_2^2\frac{\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta} & \beta_{12}\widehat{q}_2^2\frac{\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}\\ \beta_{12}\widehat{q}_2^2\frac{\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta} & \beta_{12}^2\widehat{q}_2^2\frac{\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}+\Sigma_u\end{array}\right].$$

Market maker 1 thus decides that $\lambda_2 = \frac{\beta_{12}\widehat{q}_2^2\frac{\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}}{\beta_{12}^2\widehat{q}_2^2\frac{\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}+\Sigma_u}$ and $\mu_2 = \widehat{q}_2\left(E[a|s_1,s_2]-\widehat{q}_1-\widehat{q}_2\right) - \frac{\beta_{12}\widehat{q}_2^2\frac{\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}}{\beta_{12}^2\widehat{q}_2^2\frac{\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}+\Sigma_u}\left(\alpha_{12}+\beta_{12}\widehat{q}_2\left(E[a|s_1,s_2]-\widehat{q}_1-\widehat{q}_2\right)\right)$.Solving for the unknowns, we have

$$\begin{aligned}\alpha_{12} &= -\frac{\sqrt{\Sigma_u}}{\sqrt{\frac{\Sigma_a\Sigma_\theta}{2\Sigma_a\Sigma_\theta+\Sigma_\theta}}}\left(E[a|s_1,s_2]-\widehat{q}_1-\widehat{q}_2\right),\ \beta_{12} = \frac{\sqrt{\Sigma_u}}{\widehat{q}_2\sqrt{\frac{\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}}}\\ \mu_2 &= \widehat{q}_2\left(E[a|s_1,s_2]-\widehat{q}_1-\widehat{q}_2\right),\ \lambda_2 = \frac{1}{2}\frac{\widehat{q}_2}{\sqrt{\Sigma_u}}\sqrt{\frac{\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}}.\end{aligned}$$

The price for firm 2's share is therefore $P_2\left(\widetilde{d}_{12}+\widetilde{u}\right) = \mu_2+\lambda_2\left(\widetilde{d}_{12}+\widetilde{u}\right)$, with

$$P_2(D_1) = \frac{1}{2}\widehat{q}_2\left(E[a|s_1,s_2]-\widehat{q}_1-\widehat{q}_2\right)+\frac{1}{2}\widehat{q}_2\left(\widetilde{a}-\widehat{q}_1-\widehat{q}_2\right)+\frac{1}{2\Sigma_u}\widehat{q}_2\sqrt{\Sigma_u\frac{\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}}\widetilde{u}, \tag{49}$$

and manager 1's trading profit conditional on not knowing V_2 is

$$E\left[\left(\widetilde{V}_2-\widetilde{P}_2\right)d_{12}\right] = \frac{\widehat{q}_2}{2}\sqrt{\Sigma_u\frac{\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}}. \tag{50}$$

In the first stage, manager 1 decides his production quantity $\widehat{q}_1$ by maximizing his total payoff. His problem is:

$$\begin{aligned}&\max_{\widehat{q}_1}\omega E\left[\widetilde{V}_1\right]+E[\Pi_1]\\ =\ &\omega\widehat{q}_1\left(E[a|s_1,s_2]-\widehat{q}_1-\widehat{q}_2\right)+\frac{\widehat{q}_2}{2}\sqrt{\Sigma_u\frac{\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}}\end{aligned} \tag{51}$$

Manager 2's problem is symmetric. Applying symmetry and solving for the production quantity, we have $\widehat{q}_1 = \widehat{q}_2 = \frac{1}{3}E[a|s_1,s_2]$.

K Proof of Corollary 4.1

Knowing $\widehat{q}_i = \widehat{q}_j = \frac{1}{3}E[a|s_i,s_j]$, we can compute manager i's ex-ante expected insider trading profit

$$E\left[\widetilde{\Pi}_i\right] = E\left[\left(\widetilde{V}_j-\widetilde{P}_j\right)d_{ij}\right] = \frac{E[\widehat{q}_i]}{2}\sqrt{\frac{\Sigma_u\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}} = \frac{m_a}{6}\sqrt{\frac{\Sigma_u\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}}, \tag{52}$$

and the expected firm value of firm i is

$$E\left[\widetilde{V}_i\right]=\frac{1}{9}\left(E\left[\frac{\Sigma_\theta m_a+\Sigma_a\left(\widetilde{s}_i+\widetilde{s}_j\right)}{2\Sigma_a+\Sigma_\theta}\right]\right)^2=\frac{m_a^2}{9}. \tag{53}$$

L Proof of Proposition 5:

The board's program is:

$$\max_{\alpha,\omega} E\left[V-(\alpha+\omega V)\right] \tag{54}$$

subject to individual rationality (IR) condition

$$E\left[\Pi\right]+\alpha+\omega E\left[V\right]\geq 0. \tag{55}$$

Plugging the binding IR condition into the board's objective function, it simplifies to $\max_\omega E\left[V\right]+E\left[\Pi\right]$. We then substitute $E\left[V\right]$ and $E\left[\Pi\right]$ into the board's objective function, and get

$$\max_\omega \frac{1}{16\omega^2}\left(4\omega^2 m_a^2-\frac{\Sigma_u\Sigma_a\Sigma_\theta}{\Sigma_a+\Sigma_\theta}\right)+m_a\sqrt{\frac{\Sigma_u\Sigma_a\Sigma_\theta}{\Sigma_a+\Sigma_\theta}}+\frac{1}{2\omega}\frac{\Sigma_u\Sigma_a\Sigma_\theta}{\Sigma_a+\Sigma_\theta}. \tag{56}$$

Taking the first order condition w.r.t. ω, we have $\frac{1}{8\omega^3}\left(1-4\omega\right)\frac{\Sigma_u\Sigma_a\Sigma_\theta}{\Sigma_a+\Sigma_\theta}$. Setting it to equal zero and solving for ω, we get $\omega=\frac{1}{4}$.

In our model, the optimal ω is a constant because of the stylized setting. The parameters simply drop out due to the linear demand functions in both the product and financial market. Checking for second order condition, we take the second order derivative w.r.t. ω and get $\frac{1}{8\omega^4}\left(8\omega-3\right)\frac{\Sigma_u\Sigma_a\Sigma_\theta}{\Sigma_a+\Sigma_\theta}$, which is negative when $\omega=\frac{1}{4}$. Thus we know the second order condition is satisfied.

M Proof of Proposition 6:

The program of firm i's board's is:

$$\max_{\alpha_i,\omega_i} E\left[V_i-(\alpha_i+\omega_i V_i)\right] \tag{57}$$

subject to individual rationality (IR) condition

$$E\left[\Pi_i\right]+\alpha_i+\omega_i E\left[V_i\right]\geq 0. \tag{58}$$

Substituting the binding IR condition into the board's objective function, it becomes $\max_{\omega_i} E\left[V_i\right]+E\left[\Pi_i\right]$. Then we substitute $E\left[V_i\right]$ and $E\left[\Pi_i\right]$ into the board's objective function, and get

$$\begin{aligned}&\max_{\omega_i}\frac{1}{12\omega_i}\frac{\Sigma_u\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}+\frac{m_a}{6}\sqrt{\frac{\Sigma_u\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}}\\&+\frac{1}{6\omega_i}\left(2\omega_i m_a+\sqrt{\frac{\Sigma_u\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}}\right)\left(m_a-\left(\frac{1}{3\omega_i}\left(2\omega_i m_a+\sqrt{\frac{\Sigma_u\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}}\right)\right)\right)\end{aligned} \tag{59}$$

Taking the FOC w.r.t. ω_i, we get $\frac{1}{36\omega_i^3}\left((4-3\omega_i)\frac{\Sigma_u\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}+2\omega_i m_a\sqrt{\frac{\Sigma_u\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}}\right)$. Setting it to equal zero and solving for ω_i, we get $\omega_i^* = \frac{4\frac{\Sigma_u\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}}{3\frac{\Sigma_u\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}-2m_a\sqrt{\frac{\Sigma_u\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}}}$. The numerator $4\frac{\Sigma_u\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}$ is larger than the denominator $3\frac{\Sigma_u\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}-2m_a\sqrt{\frac{\Sigma_u\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}}$, so $\omega_i^* > 1$ has to be true. Since ω_i^* must fall in the range of $[0,1]$, we know $\omega_i^* = 1$ is the only viable solution. Checking for second order condition, we take the second order derivative w.r.t. ω and get $-\frac{1}{18\omega_i^4}\left((6-3\omega_i)\frac{\Sigma_u\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}+2m_a\omega_i\sqrt{\frac{\Sigma_u\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}}\right)$, which is negative when $0 \leq \omega_i \leq 1$. Thus we know the second order condition is satisfied.