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Document Version
Accepted author manuscript

Published in:
Management Science

DOI:
10.1287/mnsc.2020.3915

Publication date:
2022

License
Unspecified

Citation for published version (APA):
Chen, H., & Jørgensen, B. N. (2022). Insider Trading, Competition, and Real Activities Manipulation. *Management Science*, *68*(2), 1497-1511. https://doi.org/10.1287/mnsc.2020.3915

Insider Trading, Competition, and Real Activities Manipulation

Abstract

We consider a setting where managers manipulate the firms' real activities in anticipation of insider trading opportunities. Managers choose strictly higher production quantities than the quantities chosen absent insider trading, implying lower firm profit but higher consumer surplus. Through comparative statics, we show the overproduction is mitigated by the degree of competition in the industry, the manager's current equity stake in the firm, and the precision of cost information. We also analyze the effects of insider trading in several extensions including asymmetric ownership structure, potential horizontal merger, and common market maker.

1 Introduction

Managers often use accounting discretion to profit from insider trades.[1] Numerous analytical studies (Kim and Verrecchia, 1994; Bushman and Indjejikian, 1995; Huddart, Hughes, and Levine, 2001; etc.) as well as empirical evidences (Penman, 1982; Elliott, Morse, and Richardson, 1984; Rogers and Stocken, 2005; Jagolinzer, 2009; etc.) show that managers use various disclosure strategies to obtain insider trading gains. In this study, we examine how managers can obtain insider trading benefits by manipulating real operating activities, which has not been previously explored. Managers are in a convenient position to do so: they not only have access to the firms' private information, but also control the firms' operations. Specifically, we show that managers can exploit their control over the firms' production quantity decisions to maximize private benefits from insider trading. Consequently, the managers' insider trading incentives also affect the competition in the product market.

Our model economy consists of identical firms competing in a Cournot product market. Each firm is run by a risk-neutral manager. The firms share a common production cost, which is uncertain. The managers must plan for their firms' production based on the expected operational cost. The products are then produced and sold to the final consumers, and the firms' actual costs and profits are realized and observed by the managers. Then the managers can trade in the securities of *all* firms in the market in a Kyle setting, for private benefits. The focus of our analyses is to examine the managers' production decisions and stock-trading decisions, as well as the effects on the product market competition.

We show that allowing the managers to trade in the financial market creates incentives to increase production quantity to a level strictly higher than optimal absent insider trading. This result obtains because the managers' expected ex-ante insider trading profit is an increasing function of the volatility of the firm value. A higher volatility implies more

[1] Under U.S. law, insider trading can be legal or illegal. Corporate insiders may trade their firms' stocks legally in compliance with government regulations and their firms' policies. However, trading a stock in violation of fiduciary duty or confidence while possessing insider information would be prosecuted by the SEC.

information asymmetry between the managers and the rest of the financial market, hence higher personal gains from trading for the managers. Our model describes a setting where the production quantity amplifies the volatility of the firm value, which gives the managers incentives to overproduce. The overproduction undermines firm value but improves social welfare, since a higher output leads to increased consumer surplus. We thus demonstrate that the presence of insider trades may mitigate the underproduction problem caused by imperfect competition in the product market.

Through comparative statics, we show both expected firm value and insider trading profits decrease in the number of firms in the industry. This is intuitive since competition drives down profitability in both financial and product markets, holding everything else equal. The market impact, measured by Kyle's lambda, also decreases in the number of firms in the industry. The more firms there are, the less the price moves with the order flow. Further, the production quantity distortion and insider trading profit decrease in the manager's current equity stake in the firm, while the expected firm value increases in the equity stake. These results hold because the manager's incentive is more aligned with the shareholders when the stake in the firm is high. In addition, accounting system with higher precision results in lower trading profit and weaker incentive for the manager to distort production quantities. The precision of information is thus positively related to the expected final firm value.

A key assumption in our model is that the firms' production is based on expected cost instead of actual cost. Production takes place *before* the cost uncertainty is resolved, and the cost uncertainty only affects the managers' trading decisions. This is a very common practice in reality, where many firms adopt standard costing system for production planning purpose. They would first set up a budget by estimating the expected costs required for the operations, such as direct materials, direct labor, and overhead. Then production takes place according to the budget. Any discrepancy between the actual costs and the budgeted costs is assigned to cost variance, and added into the firm's final profit. The advantage of this design is that it conveniently maintains the normal distribution of firm profit so that the Cournot model and the Kyle model can be combined in the analyses.[2]

We then discuss four additional scenarios extended from the basic model. First, we examine different ownership structures in the market. Specifically, we consider the case where a portion of firms in the market are publicly traded while the rest are privately owned. Managers of all firms trade the shares of the public firms, since the shares of the private firms are not available on the stock market. The public firms' managers overproduce to increase their insider trading gains just as in the basic model. However, the private firms' managers do not have incentives to overproduce since their firms' shares are not traded. In fact, they also benefit from the higher production quantities of the public firms through trading those firms' shares. Trading off the equity stakes in their own private firms and gains from trading their publicly owned rivals' shares, the private firm manager's best response is underproduction. Consequently, the private firms' profit is lower and the public firm's profit is higher than when there is no insider trading. This suggests that private firms could be disadvantaged when competing with public firms in the same industry.

In the second extension, we examine the effects of horizontal merger in a industry with insider trading. A merger results in market consolidation, which implies lower total industry production output but higher profit for all firms remaining in the post-merger market. The managers may lose their jobs due to the merger, but those who survive can continue to trade the firms' shares as insiders in the post-merger market. We examine how likely the shareholders and managers would support the merger, which requires them to be better-off after the merger than before. The shareholders of the merging firms support the merger if the profit of the merged firm is higher than the *combined* pre-merger firm profits. The shareholders of the merging firms are more likely to support the merger when the managers can trade all firms' shares than when the managers do not trade. In the case of the merging

[2] This is of course not the only way to maintain the normality of firm value. For example, 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.

firms' managers, however, the potential loss is so severe that they would never support a merger attempt regardless of the trading regime.

The third scenario presents a special case of insider trading when managers trade *only* in their rivals' stocks. This could happen when managers are restricted from trading their own firms' securities, and is generally regarded as legal.[3] Empirical evidence confirms that informed traders indeed trade in their competitor firms' stocks based on insider information, especially among firms with significant market shares (Tookes, 2008). In our setting, the managers are essentially complete insiders of their rival firms, because the firms are identical and the managers' private information is about a common cost. However, they cannot directly control the rival firms' operations and do not distort production quantities. There is thus no reduction in firm value but the managers can still enjoy informational benefits from insider trading. The equilibrium insider trading gains are smaller than when they can trade all firms' shares.

At the end, we discuss when there is one common market maker in the financial market instead of separate market makers for each firm. The market maker receives demand orders and sets prices for all firms. Since the firms in our model are perfectly correlated in value, the market maker can price a firm using information from other firms' order flows. Holding everything else the same, this gives the market maker significantly more informational advantage and results in lower insider trading gains for the managers. As expected, the managers have less incentives to distort production quantities than when there are separate market makers for each firm, and the expected ex-ante firm value is higher.

To our best knowledge, we are the first to study managers' incentive to manipulate real activities for personal insider trading gains. Prior research (e.g. Kim and Verrecchia, 1994; Bushman and Indjejikian, 1995; Huddart, Hughes, and Levine, 2001) demonstrates various

[3] The legality of trading in competitors' stocks is not ubiquitous. Ayres and Bankman (2001) provide a comprehensive review and analysis on various forms of substitutes for insider trading, i.e., the trading of stocks of firms that are related to one's own firm. They conclude that trading in competitors' stocks is generally legal. Donald (2017), however, suggests that liability can be assumed under the "misappropriation theory" when informed employees trade in competitor firms' stocks.

disclosure strategies adopted by managers to increase insider trading profit. In contrast, our model shows that managers can achieve the same goal by exploiting their control over their firms' operations. Specifically, managers can increase the firms' profit volatility since the expected insider trading gains increases with the variance of the firm value. This is not limited to the mechanism of overproduction—any other measures inducing higher volatility would result in the same effect. In this paper, we consider the specific setting where the managers distort production decisions, because it provides a clean framework of analysis on managerial incentives, firm value, and social welfare.

In doing so, our paper also contributes to the rich literature on accounting information and oligopoly. Numerous early studies examine the role of disclosure and information sharing when firms compete in the same product market (eg. Gal-Or 1985; Wagenhofer 1990; Darrough 1993). More recent papers examine firms' incentives to use various other accounting mechanisms in the presence of product market competition, such as earnings management (Bagnoli and Watts 2010), pre-commitment (Corona and Nan 2013, Heinle and Verrecchia 2015), and accounting conservatism (Friedman et al. 2016; Chen and Jorgensen 2018). Cheynel and Ziv (2020) derive the equilibrium proprietary cost of voluntary disclosure as a function of market competition, Suijs and Wielhouwer (2014) take the regulator's perspective to examine the socially-optimal rule of mandatory disclosure that maximizes social welfare. We differ from these studies in that we focus on the effect of competition on real activities management instead of accruals- or disclosure-based accounting choices.

The rest of the paper is organized as follows. In section 2, we describe the setup of the model. In section 3, we present the analyses of equilibrium solution and key comparative statics. In section 4, we discuss different variations and extensions of the basic model. Section 5 concludes the paper. All proofs are included in the appendix.

2 The Model

We consider an economy with n firms, whose shares are publicly traded in the stock market. These firms make products that are perfect substitutes and compete in quantities in the product market[4]. Each firm faces a linear inverse demand function $p = a - \sum_{i=1}^{n} q_i$, where p is the unit price for the product; a is the intercept of market demand; and q_i is the output quantities produced by firm i. The firms also share the same market for input factors, thus a common cost of production $\widetilde{c}$, with $\widetilde{c} \sim N(C,\ \Sigma_c)$. Each of the n firms is run by a risk-neutral manager, who sets the production quantity for the firm.

The production takes place before the cost uncertainty is resolved. This is a very common practice among manufacturing firms, the majority of which use standard costing. The production is thus based on the expected cost rather than the actual cost. Additionally, the manager of each firm costlessly obtains a cost signal $\widetilde{s} = \widetilde{c} + \widetilde{\theta}$, with $\widetilde{\theta} \sim N(0, \Sigma_\theta)$, that helps improve the accuracy of the cost information. The precision of the signal, $\frac{1}{\Sigma_\theta}$, represents the quality of the firms' costing system. The manager of each firm plans the firm's production based on the updated expected cost $E[\widetilde{c}|s]$, with

$$\mu = E[\widetilde{c}|s] = \frac{\Sigma_\theta M + \Sigma_c s}{\Sigma_c + \Sigma_\theta}, \tag{1}$$

and the corresponding conditional variance is

$$\sigma^2 = Var[\widetilde{c}|s] = \frac{\Sigma_c \Sigma_\theta}{\Sigma_c + \Sigma_\theta}. \tag{2}$$

The managers have a subsequent opportunity to trade the shares of all firms in the market for a personal gain, denoted as Π_i for the manager of firm i. Each manager i is endowed with some interest in the firm's final value, V_i, for exogenous reasons such as restricted stock

[4] For simplicity, we assume the products are perfect substitutes, i.e. the degree of substitution between products is 1. If we relax this assumption, the insights of the analyses will not change as long as the products' degree of substitution is between 0 and 1.

as part of the compensation. We assume the managers' stakes in their firms is $0 < \omega < 1$. Each manager i would thus choose a production quantity q_i to maximize the sum of equity stake in firm i and gains from trading all firms' shares in the stock market.

Following Kyle (1985), we consider a stock market with three types of participants. The first type is the risk-neutral market makers, who set pricing rules for the stocks traded[5]. The second is the noise traders who, for exogenous reasons such as liquidity needs, trade randomly. The third is the insider-managers who work at firms whose stocks are traded. We denote manager i's demand for firm j's shares as $\widetilde{d}_{ij}$, and the demand of the noisy trader is $\widetilde{u}_j \sim N(0, \Sigma_u)$. The market maker for firm j's share observes the total order flow $\widetilde{D}_j = \sum\limits_{i=1}^{n} \widetilde{d}_{ij} + \widetilde{u}_j$, which includes the order submitted by the insiders and the liquidity trader's order u_j. However, market makers cannot distinguish d_j or u_j separately. Each market maker then sets the market price for firm j's stock, conditional on D_j, that is, $P_j(D_j) = E[V_j|D_j]$. This setting also allows us to explore some special cases of legal regimes for insider trading. If managers are not allowed to participate in trading in the financial market at all, then $d_{ij} = 0$ for every i and j. If the managers are restricted from trading their own firms' shares, but can trade rival firms' shares, then $d_{ii} = 0$.

The timeline of the events for the representative firm i is presented in Figure 1.

[5] In the basic model, we assume that every firm has its own segment of financial market, with an independent market maker and a separate group of noise traders. In section 4 of the paper, we discuss the scenario when there is one single market maker for all firms in the entire stock market.

1	2	3	4
Firm i's manager decides production quantity q_i, based on expected cost $E[\widetilde{c}|s] = \mu$.	Products made and sold. Actual cost c realized and learnt only by the manager.	Firm i's manager submits orders d_{ii} and d_{ij}, noisy trader submits u_i. Total demand for firm i' stock is D_i.	Market maker sets stock price $P_i = E[V_i|D_i]$ and executes the trades.

Figure 1: Timeline of events.

All firms are identical and move simultaneously in this game. The payoff for the shareholders of firm i is the firm's profit V_i. The payoff for the manager of firm i is $\omega V_i + \Pi_i$.

3 Analyses

The manager of firm i in our setting has two decision variables: firm i's production quantity and the manager's own demand for the shares. The market maker's problem is to set price for the firm's stock. Manager i chooses production quantity q_i^* at time 1 so as to maximize:

$$\begin{aligned} & E\left[\omega \widetilde{V}_i\left(q_i^*\right)\right] + E\left[\Pi_i\left(q_i^*\right)\right] \\ = \quad & \omega E\left[q_i^*\left(a - (\widetilde{c}|s) - q_i^* - \sum_{j=1}^{n} q_j^*\right)\right] + E\left[\sum_{j=1}^{n} \Pi_{ij}\left(q_i^*\right)\right]. \end{aligned} \tag{3}$$

Given q_i^*, firm i's value is normally distributed with $\widetilde{V}_i \sim N\left(q_i^*\left(a - \mu - q_i^* - \sum_{j=1}^{n} q_j^*\right),\ q_i^{*2}\sigma^2\right)$. The manager's trading gain Π_i is the sum of ex-ante profits from trading the shares of all n firms, including firm i.

At time 2, the manager observes the realized production cost $\widetilde{c} = c$ or $\widetilde{V}_i = V_i$. Since c is the common cost for every firm in the industry, $V_i = V_j$. That is, when observing firm i's profit V_i, manager i knows the profit earned by every other rival firm. This essentially makes all managers in the same industry complete insiders of each other's firms.[6]

At time 3, the manager chooses the demand for each of the n firms' shares, d_{ij}, with $j = \{1, 2, ...n\}$, so as to maximize the trading profit in every firm j's shares:

$$E\left[\left(E\left[V_j|V_i\right] - \widetilde{P}_j\left(\widetilde{D}_j\right)\right) d_{ij}|\widetilde{V}_i = V_i\right]. \tag{4}$$

At time 4, the market maker for firm j's stock sets the market price by

$$P_j\left(D_j\right) = E\left[V_j|D_j = \sum_{j=1}^{n} d_{ij} + u\right]. \tag{5}$$

As is standard in the Kyle model, we focus on linear strategies of the players. That is, the manager i uses linear strategies in determining the demands for the shares of firm j by setting:

$$d_{ij}\left(E\left[V_j|V_i\right]\right) = \alpha_{ij} + \beta_{ij} E\left[V_j|V_i\right]. \tag{6}$$

The market maker for firm j's stock uses a linear pricing rule:

$$P_j\left(D_j\right) = \mu_j + \lambda_j\left(\sum_{j=1}^{n} d_{ij} + u\right). \tag{7}$$

We derive manager i's equilibrium production quantity using backward induction. We first solve the market maker's price-setting strategy and the manager i's trading strategy, so that we can compute the manager i's expected insider trading gains $E\left[\Pi\right]$ for any given q_i^* and q_j^*. We then plug $E\left[\Pi\left(q_i^*\right)\right]$ and $E\left[V\left(q_i^*\right)\right]$ into the manager's objective function and

[6] As long as the firms' cash flows are correlated to some degree, the managers will be able to benefit from trading rival firms' shares. Thus, the insight from the model still holds if the the managers are partial insiders of each other's firms.

solve for q_i^* in the symmetric Cournot setting.

Lemma 1 *When managers trade all firms' shares, manager i's expected ex-ante trading gain is*

$$E\left[\Pi_i\right] = \sum_{j=1}^{n} \frac{q_j^* \sigma \sqrt{\Sigma_u}}{(1+n)}.$$

Lemma 1 presents the expected trading profit of manager i at time 1, before the production decision is made. Recall that the term σ represents the standard deviation of the firms' production cost, and reflects the importance of information asymmetry in the financial market. The bigger σ is, the more informational advantage the insiders have, and thus the higher the insiders' trading gains. Further, a liquid market with more noise trading, i.e. a higher Σ_u, makes it easier for the insiders to mask their private information from the market makers, thus helps the insiders extract more personal gains from the trade. We can already see from Lemma 1 that production quantity q amplifies the insiders' trading gain $E\left[\Pi_i\right]$, and that managers have incentives to overproduce when they have subsequent insider trading opportunities.

Proposition 1 *When managers trade all firms' shares, there exists a unique linear equilibrium characterizing the strategies of manager i and the market maker i. Firm i's equilibrium production quantity is*

$$q_i^* = \frac{a-\mu}{(n+1)} + \frac{\sigma\sqrt{\Sigma_u}}{\omega\,(n+1)^2}.$$

Manager i's ex-ante expected insider trading gain is

$$E\left[\Pi_i\right] = n\left(\frac{(a-\mu)\,\sigma\sqrt{\Sigma_u}}{(n+1)^2} + \frac{\sigma^2\Sigma_u}{\omega\,(n+1)^3}\right),$$

and the ex-ante expected firm value for firm i's

$$E\left[V_i\right] = \frac{(a-\mu)^2}{(n+1)^2} - \frac{n\sigma^2\Sigma_u}{\omega^2 (n+1)^4}.$$

It is clear that allowing insider trading distorts the managers' incentive when making the quantity decision for their own firms. Since the mean and the variance of the final firm value are both functions of q^*, the quantity decision affects the manager's subsequent trading decision as well as the market maker's pricing strategy. When managers are allowed to trade freely, the production quantities are strictly higher. This result occurs because the managers' ex ante trading profits, $E\left[\Pi_i\left(q_i^*\right)\right]$, are increasing in q^*. The managers thus have incentives to increase the production quantities beyond the profit-maximizing level, which results in a firm value $E\left[V_i\right]$ that is lower than the optimal level in the absence of insider trading. The second term of $E\left[V_i\right]$, $\frac{n\sigma^2\Sigma_u}{\omega^2(n+1)^4}$, captures the loss in firm value due to managers' insider trading.

3.1 Welfare

One implication of the increased total industry production output is the potentially improved consumer welfare as a result of overproduction due to insider trading. The consumers of the real goods will therefore enjoy a lower selling price of the firms' products and higher consumer surplus. Following Mas-Collel et al. (1995), we compute the consumer surplus, denoted as CS.

$$CS = \int_0^Q \left(p\left(q\right) - p^*\right) dq = \frac{1}{2}Q^2,$$

where $p\left(q\right) = a - nq_i^*$, and q_i^* is the equilibrium production quantity and p^* is the equilibrium price for the product. We denote the total surplus as

$$TS = CS + nV_i. \tag{8}$$

The welfare effect is presented in Corollary 1.

Corollary 1 *Consumer surplus and total surplus are higher when managers trade all firms' shares than when managers do not trade.*

Consumer surplus is higher when managers can trade all firms' shares, due to the increased production quantity as shown in Proposition 1. Although firm value is lower with insider trading than without, the improvement in consumer surplus is greater than the reduction in expected firm value. Therefore, the total surplus is also higher in the presence of insider trading.

3.2 Comparative statics

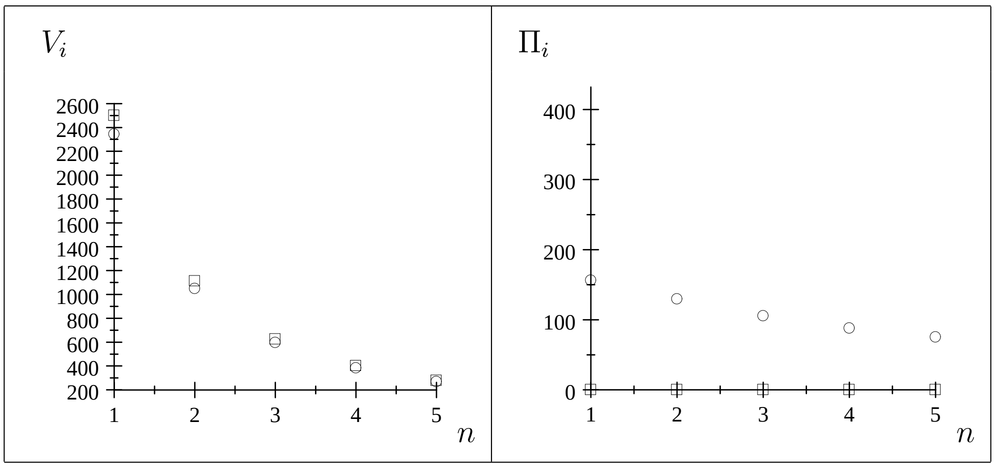
3.2.1 Market competition

Absent insider trading, increased product market competition always drives down firm profit. This is evident from the first term of $E[V_i]$, which represents the optimal level of firm value without insider trading. However, the second term of $E[V_i]$ also decreases in n, i.e., the loss in firm value due to insider trading diminishes as the number of firms goes up. Thus, the effect of n on $E[V_i]$ is not always monotonous. We summarize the effects of market competition on expected firm value and managers' insider trading gain in Corollary 2.

Corollary 2 *When managers trade all firms' shares, their ex-ante trading gains decrease in n, the degree of competition. The expected firm value decreases in n if $\frac{(3n-1)}{(n+1)^2}\sigma^2\Sigma_u < 2\omega^2(a-\mu)^2$, and increases in n otherwise.*

While the managers' insider trading gains $E[\Pi_i]$ strictly decrease in the number of firms in the market, the firm value $E[V_i]$ only decrease in n when n's negative effect on the optimal firm value dominates. When n's effect on the second term of $E[V_i]$ dominates, the expected firm value would *increase* in the market competition. This is because competition in the financial market drives down the managers' incentive to distort production quantity faster than its effect in the product market, thus $E[V_i]$ could increase in n when n is small. Observing the required condition, we see that it is more likely to be satisfied when n is sufficiently large given the parameter values.

Figure 2 provides a numerical illustration of Corollary 2.



Box: no insider trading; circle: trade all firms' shares;

Values: $a - \mu = 100$; $\sigma^2 \Sigma_u = 25$; $\omega = 0.1$

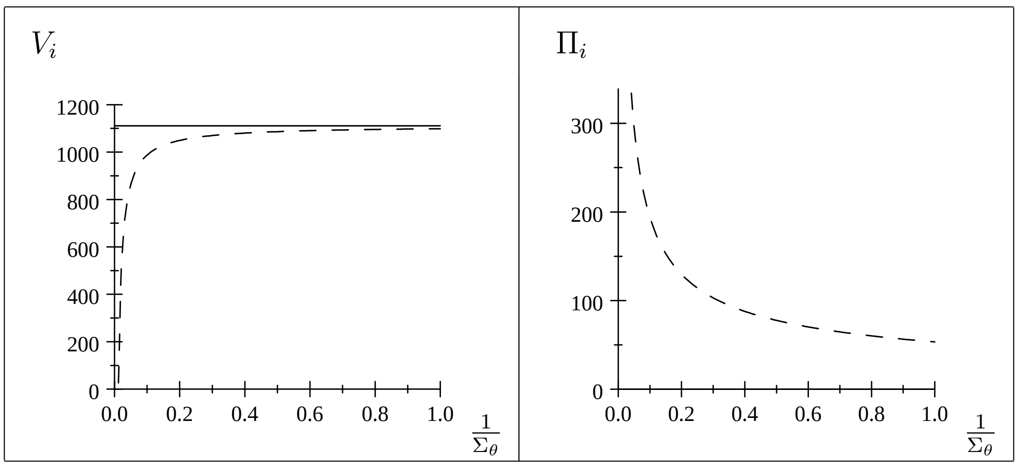
Figure 2: Firm value and insider trading gain as functions of number of firms

3.2.2 Information Precision

The precision of the costing system, $\frac{1}{\Sigma_\theta}$, affects the magnitude of the information asymmetry between the managers and the rest of the financial market. A larger information asymmetry results in a higher expected personal trading gain for manager i, which provides incentive to deviate from the profit-maximizing level of production quantity. We present the effects of $\frac{1}{\Sigma_\theta}$ on the expected firm value and managers' trading gain in Corollary 3.

Corollary 3 *Manager i's ex-ante expected trading gain* $E[\Pi_i]$ *decreases, and the expected firm value* $E[V_i]$ *increases, in the information precision* $\frac{1}{\Sigma_\theta}$.

The manager's ex-ante trading profit is a function of the variance of the firm's value. The higher the variance, the higher the informational advantage the insider has. A more precise costing system reduces the variance of the firm value, and thus affects the manager's expected trading profit in a negative way. The information precision $\frac{1}{\Sigma_\theta}$ does not affect the *expected* optimal firm value in the absence of insider trading, i.e., the first term of $E[V_i]$. However, since it reduces the manager's ex-ante trading gains as well as incentives to distort the quantity decision, a precise costing system would thus mitigate the production quantity distortion and improve expected total firm value.



Solid: no insider trading; dash: trade all firms' shares

Values: $a - \mu = 100$; $\sigma^2 \Sigma_u = 25$; $\omega = 0.1$

Figure 3: Firm value and insider trading gain as functions of information precision

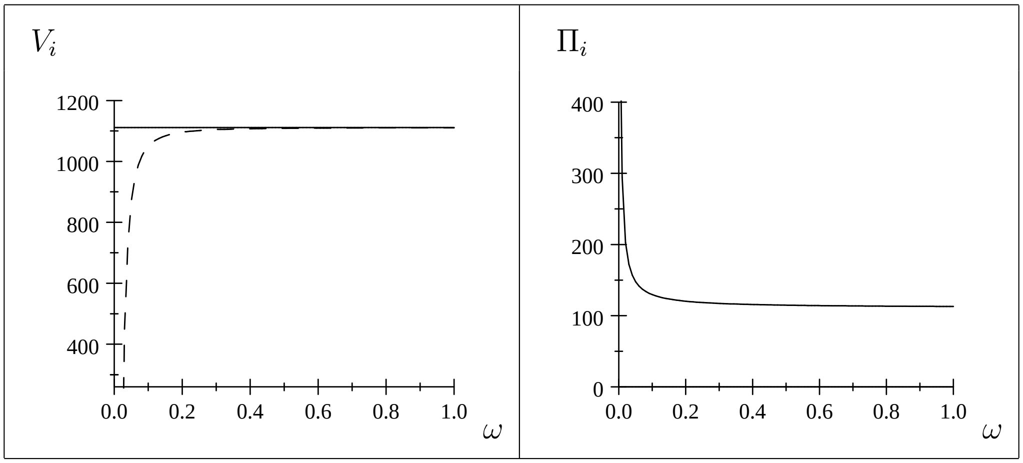
3.2.3 Managers' equity ownership

Another important parameter in the model is ω, the managers' portion of equity ownership. The manager's equity stake ω serves to mitigate the manager's incentive distortion. Essentially, the manager trades off the current stake in the firm and the personal gain from insider trades when making the production quantity decision. We also explore whether there is a level of ω that the firms' shareholders prefer, if a compensation contract in the form of

$S_i = \alpha_i + \omega_i V_i$ could be offered to the managers at time 0, with α_i being the fixed salary and ω_i being the manager's equity stake in the firm value. The shareholders aims to maximize the firm value V_i net of the compensation paid to the manager, i.e. $E\left[V_i - (\alpha_i + \omega_i V_i)\right]$, subject to the usual participation and incentive compatibility conditions.

Corollary 4 *Manager i's ex-ante expected trading gain $E\left[\Pi_i\right]$ decreases, and the expected firm value $E\left[V_i\right]$ increases, in the managers' equity ownership ω. If the shareholders of the firm could offer a compensation contract $S_i = \alpha_i + \omega_i V_i$, the optimal portion of managers' ownership is $\omega^* = \frac{2}{n+1}$ when managers trade all firms' shares.*

In this simplified setting, there is no other tension such as moral hazard problem. The shareholders only try to minimize the loss in firm value due to managers' incentives to overproduce. When managers trade all firms' shares, the optimal equity ownership granted by the shareholders is a decreasing function of the number of firms in the industry. When there are more firms in the market, the higher number of insiders compete down the insider trading gains for each other. Therefore, the manager's incentive to distort production quantity quickly diminishes, and the shareholders no longer need to rely on granting equity ownership to mitigate the managers' overproducing incentives.



Solid: no insider trading; dash: trade all firms' shares

Values: $a - \mu = 100$; $\sigma^2 \Sigma_u = 25$; $\omega = 0.1$

Figure 3: Firm value and insider trading gain as functions of managers' equity stake

4 Discussions and extensions

4.1 Public vs. private firms

So far we assumed all firms are publicly-traded. What if some firms in the industry are privately owned? Both types of firms still compete in the product market in the same manner as in the basic model, but only the public firms' shares can be freely traded in the financial market since the private firms' shares are not available. The managers of both public and private firms possess insider information of the industry, but they can only trade the shares of the public firms. We examine whether this variation in the firms' ownership structure affects the managers' equilibrium behavior and firms' profitability.

We assume that, out of the n firms in the market, the shares of firm 1 to firm k are owned privately (denoted with subscript o) and the shares of firms $k+1$ to n are traded publicly (denoted with subscript t). Since the shares of firms 1 to k are not available in the financial market, the managers of all n firms trade the shares of firms $k+1$ to n. This requires the demand orders on the shares of firms 1 to k is zero, i.e., $d_{ij}=0$ when $j \in (1,k)$. The objective function of a private firm's manager at time 2 is

$$\begin{aligned} \max_{q_{oi}} &= \omega E\left[V_{oi}\right] + E\left[\Pi_{oi}\right] && (9) \\ &= \omega q_{oi}\left(a - \widetilde{c} - q_{oi} - \sum_{j=1}^{n} q_{oj} - \sum_{j=k+1}^{n} q_{tj}\right) + \sum_{j=k+1}^{n} \frac{q_{ti}\sigma\sqrt{\Sigma_u}}{(1+n)}, && (10) \end{aligned}$$

while the objective function of a public firm's manager at time 2 is

$$\begin{aligned} & \max_{q_{ti}} \omega E\left[V_{ti}\right] + E\left[\Pi_{ti}\right] \\ = \ & \omega\left(q_{ti}\left(a - \mu - q_{ti} - \sum_{j=1}^{k} q_{oj} - \sum_{j=k+1}^{n} q_{tj}\right)\right) + \sum_{j=k+1}^{n} \frac{q_{ti}\sigma\sqrt{\Sigma_u}}{(1+n)}. \qquad (11) \end{aligned}$$

A key observation from their objective functions is that $E\left[\Pi_{oi}\right]$ and $E\left[\Pi_{ti}\right]$ both contain q_{ti}. That is, both public and private firms managers benefit from high production quantities of the *public* firms, but the private firms managers cannot control the public firms' production.

Proposition 2 *When there are both public and private firms competing in the Cournot product market, and all managers trade the shares of the public firms, the public firms overproduce and private firms underproduce in equilibrium. The profit of public firms is strictly higher than the private firms.*

Proposition 2 shows that public firms are better-off while the private firms are disadvantaged when competing in the same industry. For the managers of the public firms, their insider trading incentives lead them to overproduce, in the same way as in the basic model. However, the managers of the private firms cannot trade their own firms' shares and thus have no incentive to overproduce. Furthermore, they anticipate overproduction by their publicly traded rivals, which also benefits them through their trading of the public firms' shares. Therefore, private firm managers do not intend to retaliate and also overproduce;

instead, their best response is to underproduce. The equilibrium level of underproduction in private firms is thus determined by the managers' trade-off between their insider trading gains through the public firms' shares and the equity stake in their own firms. Consequently, in the Cournot market where some firms overproduce and some other underproduce, the overproducing firms enjoy higher profits while the private firms' profitability suffers.

4.2 Horizontal Merger

In this section, we explore the effects of potential mergers in the industry in the presence of insider trading. In the conventional analyses of horizontal mergers, firms' pre-merger and post-merger profits are compared to evaluate the propensity and efficiency of these mergers. We consider here not only the firms' profits, but also the manager's personal payoffs in the merger process. Management plays an important role in mergers and acquisitions, and their preference could also affect the decisions to combine businesses.

Suppose that out of the n firms in the industry, m firms merge into *one* new company. That is, there are $n-m+1$ firms left in the post-merger market. We make a few simplifying assumptions about the changes brought forth by the merger. First, since there is no fixed cost in the production and the marginal cost is constant,[7] the newly emerged firm behaves just like all the other remaining firms in the market in a symmetric manner. The product market is thus equally shared by $n-m+1$ firms. Second, out of the m managers that previously worked for the firms that merged, only one manager survives the merger and becomes the manager of the new firm. The other managers lose their jobs and drop out of the markets. Thus, the probability of each of the m managers survives is $\frac{1}{m}$, and the number of managers/insiders post merger is $n-m+1$. Third, only one market maker and the associated noise traders of the previous m firms survive the merger, while the other

[7] Since we do not add any additional effects such as economy of scale or synergy to the merger, all benefits of the merger stems from the decreased competition in the product market. This setting can thus be understood as a most stringent benchmark for mergers to take place.

market makers and noise traders drop out.[8] Proposition 3 summarizes the investors' and the managers' attitude toward the merger.

Proposition 3 *The shareholders of the m firms are more likely to support the merger when the managers trade all firms' shares than when the managers don't trade any shares or trade only rival firms' shares. The managers of the m firms never support the merger under any trading regimes.*

The shareholders and managers of the m firms will only support the merger if their respective payoffs are higher after the merger. For the shareholders of the merging firms, the post-merger profit of the newly merged firm must be higher than the *combined* pre-merger profits of all m firms. For the managers of the merging firms, who have only a probability of $\frac{1}{m}$ to survive the merger, their expected post-merger payoffs including both equity stake and insider trading gains must be higher than their pre-merger payoffs for them to support the merger. When the managers don't trade any shares, the production quantities and firm profits are not distorted. The result is thus the same as in the traditional horizontal merger models, requiring a significant part of the industry to merge into one firm for the shareholders of the m firms to support the merger. Specifically, $\frac{1}{(n-m+2)^2} > \frac{m}{(n+1)^2}$ must be satisfied for the post-merger firm value to be higher than the combined pre-merger firm value of the m firms. When the managers trade all firms' shares, the firms' production quantities are distorted and the firm profits are lower than optimal. However, this distortion results in a post-merger firm profit that is more likely to be higher than the combined pre-merger firm profits, given m and n. Hence, the shareholders are more likely to support the merger. Compared to the shareholders, the managers of the m firms risk losing not only their pre-merger jobs, but

[8] One disadvantage of this approach is that the total noise in trading decreases as the number of firms goes down. Alternatively, we could assume that the noise traders of the previous n firms reshuffle into the current $n-m+1$ firms. In this case, the total trading noise remains the same, but the variance of the noise trader's demand for any firm i changes from Σ_u to $\left(\frac{n}{n-m+1}\right)^2 \Sigma_u$. With this alternative assumption, all the insights from the following analyses still hold true.

also their insider trade benefits. Thus, the managers of the m firms would never support a merger.

4.3 Trading rival firms' shares only

Sometimes managers are restricted from trading their own firms' stocks due to company policies and other legal or fiduciary constraints. They could trade instead in "substitute stocks", shares of firms that are correlated with their firms' value, such as suppliers, customers, or competitors. The managers would still have at least partial insider information, but are typically subject to much less legal scrutiny than trading own firms' stocks (Ayres and Bankman, 2001). Specifically, Tookes (2008) documents empirical evidence of informed trading of rival firms' stocks based on insider information, especially among firms with high market shares.

In this section, we examine the special case of managers trading rival firms' shares only. Everything proceeds in the same way as in the basic model, except that manager i's demand order for firm i is zero, i.e. $d_{ii} = 0$. This implies that the managers obtains all of their trading gains from other firms' shares, and therefore have no incentive to inflate their own firms' production quantities. The equilibrium solution is presented in Proposition 4.

Proposition 4 *When managers only trade in rival firms' shares, the equilibrium production quantity is not distorted. The expected firm value $E[V_i]$ remains at optimal level, and the managers' expected trading gains $E[\Pi_i]$ is lower than when managers can trade all firms' shares.*

Since manager i's expected trading gain is the sum of gains from trading all $j \neq i$ firms' shares, his own firm's production quantity q_i does not affect his subsequent trading decision. Therefore, the firms' equilibrium production quantities are not distorted and the firm value is at optimal level. The managers still obtain some gains from trading, but the expected trading gain is smaller than when they could trade all firms' shares.

4.4 Common market maker

So far we assumed separate market makers for each firm in the financial market, which implies that the market makers only know about the demand orders for the firms' stocks that they are responsible for. In this section, we assume there is only *one* market maker in the entire financial market, who receives demand orders and sets market prices for all firms in the market. The financial market functions in the same way, but the common market maker has more informational advantage than the separate market makers in the basic model. This setting is thus more realistic, by capturing the information spillover among related firms.

Same as before, the total demand order for firm j is

$$\widetilde{D}_j = \sum_{i=1}^{n} d_{ij} + \widetilde{u},$$

where $\widetilde{u}$ is the noise trader's demand.[9] The market maker's linear pricing function for firm j now includes the demand orders for other firms

$$P_j\left(\widetilde{D}_1, \widetilde{D}_2...\widetilde{D}_n\right) = \mu_j + \sum_{i=1}^{n} \lambda_{ij} \widetilde{D}_i, \tag{12}$$

where λ_{ij} denotes the market maker's weight on firm i's total demand order when pricing firm j. Therefore, d_{ij}, manager i's demand order for firm j's shares, also affects the pricing of firms beyond j. As a result, manager i's objective function when determining d_{ij} is

$$\max_{d_{ij}} \sum_{j=1}^{n} E\left[\left(\widetilde{V}_j - \mu_j - \left(\sum_{i=1}^{n} \lambda_{ij} \widetilde{D}_j\right)\right) d_{ij} | \widetilde{V}_j = V_j, \right], \tag{13}$$

which includes his expected gains from trading all firms' shares, where d_{ij} is included and used by the market maker for pricing purpose.

[9] The noise in the demand for each firm's shares is the same as in the basic model. If we let the noise traders from the whole stock market trade every firms' shares, then the variance of noise in each demand flow $\widetilde{D}_j$ would be $n^2 \Sigma_u$ instead of just Σ_u.

We present the equilibrium solution in Proposition 5.

Proposition 5 *When there is one common market maker for all the firms in the whole stock market, and managers trade all firms' shares, the quantity distortion is smaller than when there are market makers for each firm. The expected value* $E[V_i]$ *is higher, and the managers' expected trading gain* $E[\Pi_i]$ *is lower, than when there are market makers for each firm.*

The intuition of Proposition 5 is straightforward. In our setting, the managers are perfect insiders of each others' firms. Holding the amount of noise trading same as before, the single market maker now has significantly more informational advantage than the firm-specific market makers in the basic model. This results in reduced insider trading gains for the managers. As expected, the managers have less incentives to distort production quantities than when there are separate market makers for each firm, and the expected firm value is hence also less damaged.

5 Conclusion

In this paper, we examine the real effects of insider trades—how insider trading opportunities affect the preceding operating decisions made by firm managers. We identify and evaluate a previously overlooked consequence of insider trading: real activities manipulation to increase the information asymmetry between the managers and other market participants. Specifically, we study insider trading in a setting where firm managers can make production decisions in anticipation of subsequent insider trading opportunities. The production quantity amplifies the variability of future firm value, and leads to larger informational advantage for the managers. through which operating decisions also influence subsequent insider trades. We demonstrate that optimal production quantity chosen in anticipation of subsequent insider trades is strictly higher than when insider trading is prohibited, leading to lower expected firm value but higher consumer surplus.

Our results are empirically testable. We predict that a firm whose executives engage in insider trades are more likely to manipulate real activities and overproduce. However, three factors may mitigate the overproduction problem at firm level. First, overproduction should decrease in the degree of competition within the industry in which the firm operates. Although competition generally increases the total production output of an industry, its effect on a single firm's output is strictly negative. Holding everything else equal, overproduction should be inversely associated with the degrees of competition, in both product markets and financial markets.[10] Second, we expect the magnitude of overproduction decreases in the executives' stock ownership. Higher percentage of stock ownership better aligns the executives' interest with firm value, and lowers their incentive to deviate from optimal production decisions. Third, the precision of accounting information should be inversely related to the executives' manipulation of real activities. Information precision reduces the information asymmetry between the corporate insiders and the rest of the market, thus lowering their expected trading gains.

Although our model focuses on the specific mechanism of overproduction, other operational decisions could also lead to the same desired result for the managers by increasing their relative informational advantage as insiders. Especially, firm managers may have incentives to purposefully increase the volatility of the firm performance through actions such as borrowing excessive amount of debt or taking overly risky investments. The opportunistic behavior would still result in suboptimal operational decisions and lower firm value.

[10] Prior research (Williams, 1995; Bolton and Scharfstein, 1990) also demonstrate that market competition could mitigate managerial misbehavior, by reducing free cash flows available to the managers.

References

[1] Ayres, I., and J. Bankman, 2001. Substitutes for insider trading. *Stanford Law Review* 54: 235–94.

[2] Bagnoli, M., S. Viswanathan, and G. Holden, 2001. On the existence of linear equilibria in models of market making. *Mathematical Finance* 11: 1–31.

[3] Bagnoli, M., and S. Watts. 2010. Oligopoly, disclosure, and earnings management. *The Accounting Review* 85 (4): 1191–1214.

[4] Bushman, R., and R. Indjejikian, 1995. Voluntary disclosures and the trading behavior of corporate insiders. *Journal of Accounting Research* 33: 293–316.

[5] Chen, H., and B. Jorgensen. 2018. Market exit through divestment: The effect of accounting bias on competition. *Management Science* 64 (1): 164–177.

[6] Chevalier, J. 1995. Capital structure and product-market competition: Empirical evidence from the supermarket industry. *The American Economic Review* 85 (3): 415-435.

[7] Cheynel, E. and A. Ziv. 2020. On Market Concentration and Disclosure. *Working paper.*

[8] Corona, C. and L. Nan. 2013. Preannouncing competitive decisions in oligopoly markets. *Journal of Accounting and Economics* 56(1), 73–90.

[9] Darrough, M., 1993. Disclosure policy and competition: Cournot vs. Bertrand. *The Accounting Review* 68: 534–561.

[10] Elliot, J., D. Morse, and G. Richardson, 1984. The association between insider trading and information announcements. *The RAND Journal of Economics* 15: 521–536.

[11] Friedman, H., J. Hughes, and R. Saouma. 2016. Implications of biased reporting: Conservative and liberal accounting policies in oligopolies. *Review of Accounting Studies* 21 (1): 251-279.

[12] Gal-Or, E. 1985. Information sharing in oligopoly. *Econometrica* 53(1):329–344

[13] Gal-Or, E. 1986. Information transmission – Cournot and Bertrand equilibria. *Review of Economic Studies* 53: 85–92.

[14] Healy, P., A. P. Hutton, and K. G. Palepu, 1999. Stock performance and intermediation changes surrounding sustained increases in disclosure. *Contemporary Accounting Research* 16(3): 485–520.

[15] Heinle, M. S. and R. E. Verrecchia. 2015. Bias and the commitment to disclosure. *Management Science* 62(10), 2859–2870.

[16] Huddart, S., J. Hughes, and C. Levine, 2001. Public disclosure and dissimulation of insider trades. *Econometrica* 69: 665–685.

[17] Jagolinzer, A., 2009. SEC rule 10b5–1 and insiders' strategic trade. *Management Science* 55: 224–239.

[18] Jain, N., and L. J. Mirman, 2000. Real and financial effects of insider trading with correlated signals. *Economic Theory* 16: 333–353.

[19] Jain, N., and L. J. Mirman, 2002. Effects of insider trading under different market structures. *The Quarterly Review of Economics and Finance* 42: 19–39.

[20] Kim, O., and R. E. Verrecchia, 1994. Market liquidity and volume around earnings announcements. *Journal of Accounting and Economics* 17: 41–67.

[21] Kyle, A., 1985. Continuous auctions and insider trading. Econometrica 53: 1315–1335.

[22] Laux, V., 2010. On the benefits of allowing CEOs to time their stock option exercises. *The RAND Journal of Economics* 41: 118–138.

[23] Mas-colell, A. M. Whinston and J. Green. Microeconomic Theory. New York: Oxford University Press, 1995.

[24] Penman, S., 1982. Insider trading and the dissemination of firm's forecast information. *Journal of Business* 55: 479–503.

[25] Suijs, J. and J. L. Wielhouwer. 2014. Disclosure regulation in duopoly markets: Proprietary costs and social welfare. *European Accounting Review* 23(2), 227–255.

[26] Wagenhofer, A. 1990. Voluntary disclosure with a strategic opponent. *Journal of Accounting and Economics* 12 (4): 341–363.

Appendix

A Proof of Lemma 1

Both the managers and the market makers use linear strategies. Let

$$d_{ij}\left(\widetilde{V}_j\right) = \alpha_{ij} + \beta_{ij}\widetilde{V}_j \tag{14}$$

be the demand manager i submits for firm j's shares, and

$$\widetilde{D}_j = \sum_{i=1}^{n} \widetilde{d}_{ij} + \widetilde{u}_j \tag{15}$$

be the total demand for firm j's shares. There is a market maker for each firm's stocks, and the market maker for firm j's stocks uses pricing strategy

$$P_j\left(\widetilde{D}_j\right) = \mu_j + \lambda_j\left(\widetilde{D}_j\right). \tag{16}$$

In equilibrium, $E\left[P_j\left(\widetilde{D}_j\right)\right] = E\left[V_j\right]$. We use backward induction to solve for the market makers' and the managers' equilibrium strategies.

A.1 Market makers' problem

The mean and variance of the updated cost signal are $\mu = \frac{\Sigma_\theta M + \Sigma_c s}{\Sigma_c + \Sigma_\theta}$ and $\sigma^2 = \frac{\Sigma_c \Sigma_\theta}{\Sigma_c + \Sigma_\theta}$, respectively. We know that $\widetilde{D}_j$, the total demand for firm j's stocks received by the market maker, is normally distributed with $\widetilde{V}_j \sim N\left(\sum_{i=1}^{n}\left(\alpha_{ij} + \beta_{ij} q_j^*\left(a - \mu - \sum_{j=1}^{n} q_j^*\right)\right),\ \beta_{ij}^2 q_j^{*2} \sigma^2 + \Sigma_u\right)$.

The market maker's sets the price as

$$P_j\left(D_j\right) = E\left[\widetilde{V}_j | D_j = \mu_j + \lambda_j\left(\sum_{i=1}^{n}\left(\alpha_{ij} + \beta_{ij}\widetilde{V}_j\right) + \widetilde{u}_j\right)\right], \tag{17}$$

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

$$\begin{bmatrix} q_j^2\sigma^2 & \beta_{jj}q_j^2\sigma^2 \\ \beta_{jj}q_j^2\sigma^2 & \sum\limits_{i=1}^{n}\beta_{ij}^2 q_i^2\sigma^2 + \Sigma_u \end{bmatrix}.$$

The market maker draws inference from observing realized total order flow $\widetilde{D}_j = D_j$ and updates her belief about $\widetilde{V}_j$ by setting

$$\lambda_j = \frac{\beta_{jj}q_j^2\sigma^2}{\sum\limits_{i=1}^{n}\beta_{ij}^2 q_i^2\sigma^2 + \Sigma_u}, \tag{18}$$

and

$$\mu_j = q_j\left(a - \mu - \sum_{j=1}^{n} q_j\right) - \frac{\beta_{jj}q_j^2\sigma^2}{\sum\limits_{i=1}^{n}\beta_{ij}^2 q_i^2\sigma^2 + \Sigma_u}\left(\alpha_{ij} + \beta_{ij}q_j\left(a - \mu - \sum_{j=1}^{n} q_j\right)\right). \tag{19}$$

A.2 Managers' trading problem

Recall the manager determines the demand d_{ij} for the firm's shares so as to maximize the expected trading profit

$$\begin{aligned} & E\left[\left(\widetilde{V}_j - \mu_j - \lambda_j\left(\widetilde{D}_j\right)\right) d_{ij} | \widetilde{V}_j = V_j\right] \\ = & \left(V_j - \mu_j - \lambda_j\left(\widetilde{D}_j\right)\right) d_{ij}. \end{aligned} \tag{20}$$

Taking the first order condition with regard to d_{ij} and setting it equal to zero, we get

$$d_{ij} = \frac{-\mu_j}{2\lambda_j} + \frac{1}{2\lambda_j}V_j. \tag{21}$$

Clearly, d_{ij} is a linear function of V_j with $\alpha_{ij} = \frac{-\mu_j}{2\lambda_j}$ and $\beta_{ij} = \frac{1}{2\lambda_j}$.

Substituting every λ_j and μ_j into (18) and (19), together with equation 14, we now have a system of $2 \times n$ equations. Solving for the unknowns, we have:

$$\alpha_{ij} = -\frac{(n+1)\, q_j \left(a - \mu - \sum_{j=1}^{n} q_j\right) + \sum_{i \neq j}^{n} q_i \left(a - \mu - \sum_{i=1}^{n} q_i\right)}{\sqrt{n q_i^2 - \sum_{j \neq i}^{n} q_j^2}} \frac{\sqrt{\Sigma_u}}{\sigma}, \tag{22}$$

$$\beta_{ij} = \frac{1}{\sqrt{n q_i^2 - \sum_{j \neq i}^{n} q_j^2}} \frac{\sqrt{\Sigma_u}}{\sigma}, \tag{23}$$

$$\mu_j = (n+1)\, q_j \left(a - \mu - \sum_{j=1}^{n} q_j\right) - \sum_{i \neq j}^{n} q_i \left(a - \mu - \sum_{i=1}^{n} q_i\right), \tag{24}$$

$$\lambda_i = \frac{1}{(1+n)} \sqrt{n q_i^2 - \sum_{j \neq i}^{n} q_j^2} \frac{\sigma}{\sqrt{\Sigma_u}} \tag{25}$$

A.3 Managers' production problem

Plugging α_{ij}, β_{ij}, μ_j, and λ_i into Equation 16, we can now compute manager i's expected ex-ante trading profit from firm j's stock:

$$\begin{aligned} E\left[\Pi_{ij}\right] &= E\left[\left(\widetilde{V}_j - P_j\left(\widetilde{D}_j\right)\right) d_{ij}\right] \\ &= \frac{q_j^2 \sigma \sqrt{\Sigma_u}}{(1+n)\sqrt{n q_i^2 - \sum_{j \neq i}^{n} q_j^2}}. \end{aligned} \tag{26}$$

Since the firms use symmetric strategies in their production quantity decisions, we have

$$E\left[\Pi_{ij}\right] = \frac{q_j \sigma \sqrt{\Sigma_u}}{(1+n)}.$$

Manager i's total ex-ante expected trading profit in all firms is thus

$$E\left[\Pi_i\right] = \sum_{j=1}^{n} \frac{q_j \sigma \sqrt{\Sigma_u}}{(1+n)}. \tag{27}$$

B Proof of Proposition 1

The expected value for firm i is

$$E\left[V_i\right] = \omega\left(q_i\left(a - \mu - q_i - \sum_{j\neq i}^{n} q_j\right)\right), \tag{28}$$

and firm i's manager's maximization problem is

$$\begin{aligned} & \max_{q_i} \omega E\left[V_i\right] + E\left[\Pi_i\right] \\ = \;& \omega\left(q_i\left(a - \mu - q_i - \sum_{j\neq i}^{n} q_j\right)\right) + \sum_{j=1}^{n} \frac{q_j^2 \sigma \sqrt{\Sigma_u}}{(1+n)\sqrt{n q_i^2 - \sum\limits_{j\neq i}^{n} q_j^2}} \end{aligned} \tag{29}$$

Taking FOC with regard to q_i and setting it equal to 0, we get

$$\omega\left(a - \mu - q_i - \sum_{j=1}^{n} q_j\right) + \frac{1}{n+1} q_i \frac{\left(n q_i^2 - \sum\limits_{j\neq i}^{n} q_j^2\right) \sigma \sqrt{\Sigma_u}}{\sqrt[2]{\left(n q_i^2 - \sum\limits_{j\neq i}^{n} q_j^2\right)^3}} = 0. \tag{30}$$

Checking for SOC with regard to q_i, we can verify that

$$-\omega - \frac{\sum\limits_{j\neq i}^{n} q_j^2 \sigma \sqrt{\Sigma_u}}{(n+1)\sqrt{\left(n q_i^2 - \sum\limits_{j\neq i}^{n} q_j^2\right)^3}} < 0 \tag{31}$$

holds true, since the term $n q_i^2 - \sum\limits_{j\neq i}^{n} q_j^2$ is always positive in equilibrium.

Every manager faces the same maximization problem, thus there are n first order conditions altogether. Adding all of them up and applying symmetry, we get

$$q^* = \frac{a - \mu}{(n+1)} + \frac{\sigma\sqrt{\Sigma_u}}{\omega (n+1)^2}. \tag{32}$$

Substituting q^* into the equations (28) and (27), we get

$$E\left[V_i\right] = \frac{(a-\mu)^2}{(n+1)^2} - \frac{n \sigma^2 \Sigma_u}{\omega^2 (n+1)^4}$$

and

$$E\left[\Pi_i\right] = n\left(\frac{(a-\mu)\,\sigma\sqrt{\Sigma_u}}{(n+1)^2} + \frac{\sigma^2\Sigma_u}{\omega\,(n+1)^3}\right).$$

C Proof of Corollary 1

The total consumer surplus and total social surplus are summarized below.

	Consumer Surplus CS	Total Surplus TS
No insider trading	$\frac{n^2}{2}\left(\frac{a-\mu}{n+1}\right)^2$	$\frac{n^2}{2}\left(\frac{a-\mu}{n+1}\right)^2 + n\left(\frac{a-\mu}{n+1}\right)^2$
Trade all firms' shares	$\frac{n^2}{2}\left(\frac{a-\mu}{n+1} + \frac{\sigma\sqrt{\Sigma_u}}{2\omega(n+1)}\right)^2$	$\frac{n^2}{2}\left(\frac{a-\mu}{n+1} + \frac{\sigma\sqrt{\Sigma_u}}{2\omega(n+1)}\right)^2 + n\left(\frac{a-\mu}{n+1}\right)^2 - \frac{n^2\Sigma_u\sigma^2}{4\omega^2(n+1)^2}$

The CS and TS when insider trading is allowed are obviously higher.

D Proof of Corollary 2

When managers trade all firms' shares, the effect of n on $E\left[\Pi_i\right]$ is

$$\begin{aligned}
& \frac{\partial}{\partial n}\left(n\left(\frac{(a-\mu)\,\sigma\sqrt{\Sigma_u}}{(n+1)^2} + \frac{\Sigma_u\sigma^2}{\omega\,(n+1)^3}\right)\right) && (33)\\
= & -\frac{\left(\omega\,(n^2-1)\,(a-\mu) + (2n-1)\,\sigma\sqrt{\Sigma_u}\right)\sigma\sqrt{\Sigma_u}}{\omega\,(n+1)^4} < 0.
\end{aligned}$$

We assume that a is sufficiently large thus $(a-\mu)$ is always positive.

The effect of n on $E\left[V_i\right]$ is

$$\begin{aligned}
& \frac{\partial}{\partial n}\left(\frac{(a-\mu)^2}{(n+1)^2} - \frac{n\Sigma_u\sigma^2}{\omega^2\,(n+1)^4}\right) && (34)\\
= & -2\frac{(a-\mu)^2}{(n+1)^3} + \frac{3n-1}{(n+1)^5}\frac{\sigma^2\Sigma_u}{\omega^2} && (35)
\end{aligned}$$

which is negative if $\frac{3n-1}{(n+1)^2}\frac{\sigma^2\Sigma_u}{\omega^2} < 2\,(a-\mu)^2$ is satisfied, and positive otherwise.

E Proof of Corollary 3

The effect of $\frac{1}{\Sigma_\theta}$ on $E\left[V_i\right]$ and $E\left[\Pi_i\right]$ are opposite of the effect of σ^2 on $E\left[V_i\right]$ and $E\left[\Pi_i\right]$, since $\sigma^2 = \frac{\Sigma_c^n\Sigma_\theta}{n\Sigma_c+\Sigma_\theta}$.

The effect of σ^2 on $E\left[V_i\right]$ and $E\left[\Pi_i\right]$ when managers do not trade is 0.

The effect of σ^2 on $E[V_i]$ when managers trade all firms' shares is

$$\frac{\partial}{\partial\sigma^2}\left(\frac{(a-\mu)^2}{(n+1)^2}-\frac{n\sigma^2\Sigma_u}{\omega^2(n+1)^4}\right) \tag{36}$$

$$= -\frac{n}{\omega^2}\frac{\Sigma_u}{(n+1)^4}<0. \tag{37}$$

The effect of σ^2 on $E[\Pi_i]$ when managers trade all firms' shares is

$$\frac{\partial}{\partial\sigma^2}\left(n\left(\frac{(a-\mu)\,\sigma\sqrt{\Sigma_u}}{(n+1)^2}+\frac{\Sigma_u\sigma^2}{\omega(n+1)^3}\right)\right) \tag{38}$$

$$= \frac{n}{2\sigma^2\omega}\frac{\left(\omega(n+1)(a-\mu)+2\sigma\sqrt{\Sigma_u}\right)\sigma\sqrt{\Sigma_u}}{(n+1)^3}>0, \tag{39}$$

since we assume $(a-\mu)>0$.

The effect of $\frac{1}{\Sigma_\theta}$ is simply the reciprocal of the effect of σ^2.

F Proof of Corollary 4

The effect of ω on $E[V_i]$ and $E[\Pi_i]$ when managers do not trade or only trade rival firms' shares is 0.

The effect of ω on $E[V_i]$ when managers trade all firms' shares is

$$\frac{\partial}{\partial\omega}\left(\frac{(a-\mu)^2}{(n+1)^2}-\frac{n\Sigma_u\sigma^2}{\omega^2(n+1)^4}\right)=\frac{2n}{\omega^3}\frac{\Sigma_u\sigma^2}{(n+1)^4}>0. \tag{40}$$

The effect of ω on $E[\Pi_i]$ when managers trade all firms' shares is

$$\frac{\partial}{\partial\omega}\left(n\left(\frac{(a-\mu)\,\sigma\sqrt{\Sigma_u}}{(n+1)^2}+\frac{\Sigma_u\sigma^2}{\omega(n+1)^3}\right)\right)=-\frac{n}{\omega^2}\frac{\Sigma_u\sigma^2}{(n+1)^3}<0. \tag{41}$$

We then solve for the optimal level of ω for the scenario when the shareholders can give the manager a contract at time 0. The program of firm i's shareholders is:

$$\max_{\alpha_i,\omega_i} E\left[V_i-(\alpha_i+\omega_i V_i)\right], \tag{42}$$

subject to individual rationality (IR) condition:

$$E[\Pi_i]+\alpha_i+\omega_i E[V_i]\geq 0. \tag{43}$$

Substituting the binding IR condition into the shareholders' objective function it becomes $\max\limits_{\omega_i} E[V_i]+E[\Pi_i]$. When managers trade in all firms' shares, we substitute $E[V_i]$ and $E[\Pi_i]$

into the shareholders' objective function and get:

$$\max_{\alpha_i,\omega_i} E\left[\left(\frac{(a-\mu)^2}{(n+1)^2}-\frac{n\Sigma_u\sigma^2}{\omega_i^2(n+1)^4}\right)+n\left(\frac{(a-\mu)\sigma\sqrt{\Sigma_u}}{(n+1)^2}+\frac{\Sigma_u\sigma^2}{\omega_i(n+1)^3}\right)\right].$$

Taking the FOC with regard to ω_i, we have

$$-n\frac{\sigma}{\omega^3}\frac{\Sigma_u}{(n+1)^4}(\omega+n\omega-2)=0, \tag{44}$$

which yields

$$\omega=\frac{2}{n+1}. \tag{45}$$

Checking SOC, we have

$$\frac{2n\sigma\Sigma_u}{\omega^4(n+1)^4}(\omega(1+n)-3),$$

which is always negative at the equilibrium with $\omega=\frac{2}{n+1}$.

G Proof of Proposition 2

The objective function of a private firm's manager at time 2 is

$$\begin{aligned}
\max_{q_{oi}} &= \omega E[V_{oi}]+E[\Pi_{oi}] \\
&= \omega q_{oi}\left(a-\widetilde{c}-q_{oi}-\sum_{j=1}^{n}q_{oj}-\sum_{j=k+1}^{n}q_{tj}\right)+\sum_{j=k+1}^{n}\frac{q_{ti}\sigma\sqrt{\Sigma_u}}{(1+n)},
\end{aligned} \tag{46}$$

while the objective function of a public firm's manager at time 2 is

$$\begin{aligned}
&\max_{q_{ti}}\omega E[V_{ti}]+E[\Pi_{ti}] \qquad (47)\\
&= \omega\left(q_{ti}\left(a-\mu-q_{ti}-\sum_{j=1}^{k}q_{oj}-\sum_{j=k+1}^{n}q_{tj}\right)\right)+\sum_{j=k+1}^{n}\frac{q_{ti}\sigma\sqrt{\Sigma_u}}{(1+n)}.
\end{aligned}$$

Taking FOCs with regard to q_{oi} and q_{ti} for each manager and setting them equal to 0, we get

$$\omega\left(a-\mu-2q_{oi}-\sum_{j=1}^{n}q_{oj}-\sum_{j=k+1}^{n}q_{tj}\right)=0 \tag{48}$$

and

$$\omega\left(a-\mu-2q_{ti}-\sum_{j=1}^{k}q_{oj}-\sum_{j=k+1}^{n}q_{tj}\right)+\frac{(n-k)\sigma\sqrt{\Sigma_u}}{(1+n)}=0. \tag{49}$$

Apply symmetry with $q_o = q_{oi} = q_{oj}$ and $q_t = q_{ti} = q_{tj}$, we have

$$\omega\left(a-\mu-(k+1)\,q_o-(n-k)\,q_t\right)=0 \tag{50}$$

and

$$\omega\left(a-\mu-(n-k+1)\,q_t-kq_o\right)+\frac{(n-k)\,\sigma\sqrt{\Sigma_u}}{(1+n)}=0. \tag{51}$$

Solving for $q_o$and q_t, we get

$$q_o=\frac{(a-\mu)}{(1+n)}-\frac{(n-k)^2\,\sigma\sqrt{\Sigma_u}}{(1+n)^2\,\omega} \tag{52}$$

and

$$q_t=\frac{(a-\mu)}{(1+n)}+\frac{(n-k)\,(1+k)\,\sigma\sqrt{\Sigma_u}}{\omega\,(n+1)^2}. \tag{53}$$

The value of a privately-owned firm is

$$E\left[V_o\right]=\frac{\left((1+n)\,\omega\,(a-\mu)-(n-k)^2\,\sigma\sqrt{\Sigma_u}\right)^2}{\omega^2\,(n+1)^4}, \tag{54}$$

and the value of a publicly-traded firm is

$$E\left[V_t\right]=\frac{\left((1+n)\,\omega\,(a-\mu)+(1+k)\,(n-k)^2\,\sigma\sqrt{\Sigma_u}\right)\left((1+n)\,\omega\,(a-\mu)-(k+2)\,(n-k)^2\,\sigma\sqrt{\Sigma_u}\right)}{\omega^2\,(n+1)^4}. \tag{55}$$

Since $q_t > q_o$, it is clear that $E\left[V_t\right] > E\left[V_o\right]$ also holds true.

H Proof of Proposition 3

The process of solving for $E\left[\Pi_i\right]$ and $E\left[V_i\right]$ with $n-m+1$ firms is the same as with n firms. Specifically, firm i's post-merger production quantity is $\frac{a-\mu}{(n-m+2)}$ when there is no insider trading, and $\frac{a-\mu}{(n-m+2)}+\frac{\sigma\sqrt{\Sigma_u}}{\omega(n-m+2)^2}$ when managers trade all firms' shares. The expected post-merger firm value and manager i's trading profit are summarized in the table below.

	Ex-ante expected insider trading profit $E\left[\Pi_i\right]$	Ex-ante expected firm value $E\left[V_i\right]$
No insider trading	0	$\frac{(a-\mu)^2}{(n-m+2)^2}$
Trade all firms' shares	$(n-m+1)\left(\frac{(a-\mu)\sigma\sqrt{\Sigma_u}}{(n-m+2)^2}+\frac{\sigma^2\Sigma_u}{\omega(n-m+2)^3}\right)$	$\frac{(a-\mu)^2}{(n-m+2)^2}-\frac{(n-m+1)\sigma^2\Sigma_u}{\omega^2(n-m+2)^4}$

Based on the payoffs specified in Proposition 1 and Table 2, we can analyze the attitude of the managers and shareholders of the m firms toward the merger by comparing their payoffs. When there is no insider trading, for the shareholders of the m firms to support the merger, the following condition must be met:

$$\frac{(a-\mu)^2}{(n-m+2)^2} > m\left(\frac{(a-\mu)^2}{(n+1)^2}\right). \tag{56}$$

Re-arrange the terms, we have

$$\frac{1}{(n-m+2)^2} > \frac{m}{(n+1)^2}. \tag{57}$$

When the managers can trade all firms' shares, for the shareholders of the m firms to support the merger, the following condition must be met:

$$\frac{(a-\mu)^2}{(n-m+2)^2} - \frac{(a-\mu)^2}{(n-m+2)^2} > m\left(\frac{(a-\mu)^2}{(n+1)^2} - \frac{n\sigma^2\Sigma_u}{\omega^2(n+1)^4}\right). \tag{58}$$

Taking a first order derivative of the terms $\frac{(a-\mu)^2}{(n-m+2)^2}$ and $m\frac{n\sigma^2\Sigma_u}{\omega^2(n+1)^4}$ with regard to m, we know that the loss in firm value due to insider trading decreases faster in m than the optimal firm value itself. Therefore, it is easier for the the condition to be satisfied when shareholders trade all firms shares than when insider trading is not allowed.

The managers of the m firms only has $\frac{1}{m}$ chance to survive the merger. Thus, for the managers of the m firms to support the merger, the following condition must be met:

$$\frac{1}{m}\left(\begin{array}{c}\left(\frac{\omega(a-\mu)^2}{(n-m+2)^2} - \frac{\omega(n-m+1)\sigma^2\Sigma_u}{\omega^2(n-m+2)^4}\right) \\ +\left(\frac{(n-m+1)(a-\mu)\sigma\sqrt{\Sigma_u}}{(n-m+2)^2} + \frac{(n-m+1)\sigma^2\Sigma_u}{\omega(n-m+2)^3}\right)\end{array}\right) > \left(\begin{array}{c}\omega\left(\frac{(a-\mu)^2}{(n+1)^2} - \frac{n\sigma^2\Sigma_u}{\omega^2(n+1)^4}\right) \\ +n\left(\frac{(a-\mu)\sigma\sqrt{\Sigma_u}}{(n+1)^2} + \frac{\sigma^2\Sigma_u}{\omega(n+1)^3}\right)\end{array}\right). \tag{59}$$

No positive integers of m and n with $m < n$ could satisfy the condition.

I Proof of Proposition 4

When managers only trade rival firms' shares, the proof is similar as for Lemma 1 and Proposition 1, but manager i cannot trade in firm i's shares. Thus the manager's total ex-ante expected trading gain is

$$E[\Pi_i] = \sum_{j\neq i}^{n} \frac{q_j\sigma\sqrt{\Sigma_u}}{(1+n)}. \tag{60}$$

Because manager i cannot control firm j's production quantity decision, and only maximizes $\omega E[V_i]$ at the time of production decision, thus the production quantity q and expected firm value $E[V_i]$ are both at optimal level with $q_i = \frac{(a-\mu)^2}{(n+1)^2}$ and $E[V_i] = \frac{(a-\mu)^2}{(n+1)^2}$.

J Proof of Proposition 5

When there is one common market maker for all the firms in the industry, the steps of proof is the same as in the proof for Lemma 1 and Proposition 1. Manager i's demand for firm j's shares is the same as shown in equation 14, and the total demand for firm j's shares is the same as in equation 15.

J.1 Market maker's problem

The market maker's linear pricing strategy for firm j's shares is described in equation 12. We know the firm value $\widetilde{V}_1$ and the firms' demand orders $\widetilde{D}_1 ...\ \widetilde{D}_n$ are jointly normally distributed with means $\begin{bmatrix} q_j\left(a-\mu-q_1-...-q_n\right) \\ \left(\alpha_{11}+\beta_{11}q_1\left(a-\mu-q_1-...-q_n\right)\right)+...+\alpha_{n1}+\beta_{n1}q_n\left(a-\mu-q_1-...-q_n\right) \\ ... \\ \left(\alpha_{1n}+\beta_{1n}q_1\left(a-\mu-q_1-...-q_n\right)\right)+...+\alpha_{nn}+\beta_{nn}q_n\left(a-\mu-q_1-...-q_n\right) \end{bmatrix}$ and a $n \times n$ var-cov matrix. Based on the order flows received from each firms, the market maker obtains

$$\lambda_{ij} = \frac{\beta_{ij}q_j^2\sigma^2}{\left(\beta_{11}^2q_1^2+...+\beta_{n1}^2q_n^2\right)\sigma^2+\Sigma_u} \tag{61}$$

and

$$\mu_j = E\left[\widetilde{V}_j\right] - \lambda_{11}E\left[\widetilde{D}_1\right] - ... - \lambda_{n1}E\left[\widetilde{D}_n\right]. \tag{62}$$

J.2 Managers' trading problem

Manager i's objective function when determining his demand order for firm j's shares is described in 13. For example, manager 1's problem when trying to decide the demand order firm 2 is

$$\max_{d_{12}} E\left[\left(\widetilde{V}_2-\left(\mu_2+\lambda_{11}\widetilde{D}_1+...+\lambda_{n1}\widetilde{D}_n\right)\right)d_{12}|\widetilde{V}_2=V_2\right], \tag{63}$$

Taking FOC of 13 and setting it equal to zero, we get a system of $n \times n$ equations.

Knowing that the managers use symmetric strategies and solving for the unknowns, we get

$$\alpha_{ij} = -\frac{q_j\left(a-\mu-\sum\limits_{j=1}^{n} q_j\right)}{\sqrt{nq_i^2-\sum\limits_{j\neq i}^{n} q_j^2}}\frac{\sqrt{\Sigma_u}}{\sigma}, \tag{64}$$

$$\beta_{ij} = \frac{1}{\sqrt{\left(n\left(n+1\right)-1\right)q_i^2-\sum\limits_{\substack{j=1\\ i\neq j}}^{n} q_j^2}}\frac{\sqrt{\Sigma_u}}{\sigma}, \tag{65}$$

$$\mu_j = q_j\left(a-\mu-\sum_{j=1}^{n} q_j\right), \tag{66}$$

$$\lambda_{ij} = \frac{1}{n\left(n+1\right)}\sqrt{\left(n\left(n+1\right)-1\right)q_i^2-\sum_{\substack{j=1\\ i\neq j}}^{n} q_j^2}\frac{\sigma}{\sqrt{\Sigma_u}} \tag{67}$$

J.3 Managers' production problem

Computing the managers i' expected trading gain from firm j's shares, we get

$$\begin{aligned} E\left[\Pi_{ij}\right] &= E\left[\left(P_j-V_j\right)d_{ij}\right] \\ &= \frac{q_j^2\sigma}{\sqrt{\left(n\left(n+1\right)-1\right)q_i^2-\sum\limits_{\substack{j=1\\ i\neq j}}^{n} q_j^2}}\frac{\sqrt{\Sigma_u}}{\sigma}. \end{aligned} \tag{68}$$

To choose production quantity q_i, Manager i's objective function is

$$\max_{q_i} E\left[\omega\left(q_i\left(a-\widetilde{c}-q_1-...-q_n\right)\right)+\sum_{j=1}^{n}\frac{q_j^2\sigma}{\sqrt{\left(n\left(n+1\right)-1\right)q_i^2-\sum\limits_{\substack{j=1\\ i\neq j}}^{n} q_j^2}}\frac{\sqrt{\Sigma_u}}{\sigma}\right]. \tag{69}$$

Taking the FOC w.r.t q_i and setting it to equal zero, and applying symmetry, we get

$$q_i = \frac{a-\mu}{n+1}+\frac{\sigma\sqrt{\Sigma_u}}{n^2\left(n+1\right)^2\omega} \tag{70}$$

J.4 Managers' insider trading gain

We can now compute the manager i's expected gain in trading firm j's shares

$$E\left[\widetilde{\Pi}_{ij}\right] = E\left[\frac{q_j^2\sigma}{n^2(n+1)\sqrt{(n(n+1)-1)q_i^2-\sum_{\substack{j=1\\ i\neq j}}^{n}q_j^2}}\frac{\sqrt{\Sigma_u}}{\sigma}\left(\widetilde{V}_j-V_j\right)^2\right] \tag{71}$$

$$= \frac{(a-\mu)\sigma}{n^2(n+1)^2}+\frac{\Sigma_u\sigma^2}{n^4(n+1)^3\omega}. \tag{72}$$

J.5 Expected ex-ante firm value

The expected firm value is thus

$$E\left[\widetilde{V}_i\right] = E\left[E[q_i]\left((a-\widetilde{c})-E[q_i]-E[q_j]\right)\right]$$

$$= \frac{(a-\mu)^2}{(n+1)^2}-\frac{n\Sigma_u\sigma^2}{n^4(n+1)^4\omega}. \tag{73}$$