

The Industrial Organization of Financial Market Information Production

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Abstract

Information-producing agents can opt to produce from the sell-side or the buy-side of a financial market. In the former case, they act as intermediaries who can only sell their information to other market participants. In the latter capacity they can trade on their own private information or that acquired from an intermediary. There are welfare gains when an agent opts to become an intermediary because financial market prices are more sensitive to information produced from the sell-side of the information market. We examine conditions under which sell-side information production is sustainable and examine the implications of the model for ongoing restructuring within the securities industry.

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JEL classification: L22, G24, G14, D82

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1 Introduction

This paper develops a model for examining the decision to become a securities market intermediary. We define a securities market intermediary as an agent who produces for direct sale (from the *sell-side* of the market) information that bears on securities prices. Intermediaries do not trade on the information they produce. The alternative to becoming a securities market intermediary is to trade securities (from the *buy-side*) in a financial market conditional on one's own private information or that acquired from a sell-side agent.

We establish that there are welfare gains when an agent opts to become an intermediary. The welfare gains arise because financial market prices respond differently to information produced from the buy-side and from the sell-side of the information market. We assume that the intermediary cannot credibly commit to sell information to a subset of the remaining information producers. The resulting threat of wide dissemination of sell-side information heightens competition among buy-side traders. In turn, information produced from the sell-side of the market is more rapidly impounded in financial market prices than would be the same information produced from the buy-side and thus reserved strictly for private trading. In short, the intermediary places competitive pressure on other information producers that would not exist had he opted to participate on the buy-side of the market.

But while the presence of an intermediary can promote welfare, a delicate balance must be struck for information-producing agents to become intermediaries. In our model, the contracting problem facing prospective intermediaries limits their capacity for covering information production costs. We identify two mechanisms by which prospective intermediaries might capture benefits created by their presence in the market. First, in a standard Kyle (1985) setting, we derive conditions under which intermediaries can extract a sufficiently large share of buy-side trading profits (gained at the expense of liquidity traders) to motivate sell-side information production. This analysis sheds light on why sell-side analyst research of the sort targeted by the recent *Global Settlement* is both more difficult to sustain and perhaps less worthy of concern were it not.¹ Sell-side analyst research may reflect greater access to firm management

¹The \$1.5 billion settlement required sell-side firms to pay \$460 million for independent research over five years, and to distribute independent research reports together with their own reports. See the Securities and Exchange Commission press release at <http://www.sec.gov/news/press/2003-54.htm> for details. Investment research is the most visible and controversial example of the industry's information production. Although there are specialized firms, like Sanford Bernstein and Value Line, for which investment research is the primary output, securities firms traditionally bundled research with other products and services either on the buy-side or the sell-side of the market. Sell-side firms, such as investment banks and brokerage firms, produce research for both wholesale (institutional investor and corporate) clients and retail clients who typically acquire it

than would be available to buy-side information producers. However, the bulk of such research almost surely reflects interpretation of public information and buy-side money-management firms maintain similar research capacity in house. If so, the competitive threat posed by sell-side information producers is small and their bargaining power with potential buy-side purchasers of their information is weak. Thus information-producing agents will have little incentive to produce information for sale when they can trade directly on their information in a liquid financial market.

The more liquid the financial market, the smaller will be any welfare losses associated with an absence of competitive pressure from sell-side information producers. Thus we conclude that direct sale of sell-side research bearing on securities trading in active secondary markets will suffer with technological advances that lead to wider and less costly information dissemination. Such technological advances amplify the contracting problem that undermines sell-side research in the first place. Where unique sell-side research capacity exists, producers will have greater incentive to trade on their information directly and thus directly increase competition on the buy-side of the information market. This suggests a shift to larger-scale, heavily capitalized firms exploiting small and fleeting informational inefficiencies.

Alternatively and, we believe, more importantly, if real investment decisions are positively influenced by information produced by sell-side intermediaries, firms will have incentive to share the welfare benefits yielded by the intermediary's decision to produce information from the sell-side of the market – high fees effectively subsidize sell-side information production which, in turn, improves investment decisions by promoting financial market efficiency. We characterize the conditions under which this occurs as similar to those arising around large corporate acquisitions or restructuring transactions. In this context, the firm effectively creates an additional bidder in the transaction by entering a relationship within which the intermediary gains unique information-production capacity and the firm shares with the intermediary any surplus associated with sell-side information production. The large fees typically associated with

bundled with other investment banking or brokerage services. Buy-side firms, like mutual funds, produce their own research in addition to that acquired from sell-side producers and bundle the research with asset management services for both retail and institutional investors. Cheng, Liu and Qian (2003) estimate that 71% of research is produced by buy-side firms, 24% by sell-side firms, and the remaining 5% by specialized firms. A substantial academic literature identifies systematic biases in analyst research [See Hong and Kubik (2003)] Recent investigations led by the New York Attorney General's office and the Securities and Exchange Commission produced evidence that some biased research was linked to conflicts of interest within the organizations producing the research. Ljungqvist, Marston and Wilhelm (2005) provide evidence that while conflicts of interest were amplified during the late 1990s, reputational considerations moderated analyst behavior and its influence over an issuing firm's choice of an underwriter.

such transactions complement or even obviate the need for financial market trading profits as a means of sustaining sell-side information production.

Large corporate transactions strain financial market liquidity, effectively narrowing the market to relatively few potential bidders. Moreover, the relatively exclusive client relationships within which investment banks advise on these transactions more likely yield unique information. In this setting, a sell-side information producer can place substantial marginal competitive pressure on bidders who might otherwise trade (i.e., bid) less aggressively with respect to their own private information and thus force such private information more rapidly into the public domain. And the high stakes nature of these transactions suggests greater potential for pronounced welfare benefits.² If this is the case, one would expect such deal-oriented, sell-side information production, of the sort associated with traditional investment banking functions (and the high fees paid for such information), to weather wider and lower cost dissemination of financial market price information.³

Our purpose in studying the decision to become a securities market intermediary is to begin laying a formal foundation for a theory of investment banking. Our definition of a securities market intermediary is in the spirit of Morrison's and Wilhelm's (2007a) characterization of investment banks as coordinators of information networks comprising entrepreneurs and potential investors. Entrepreneurs wish to condition investment decisions on feedback (private information) from investors obtained both directly and via financial market prices. Investors wish to condition their financial market trading decisions on entrepreneurs' private information about investment projects. The investment bank's economic function is to promote exchange of private information within the network.

Morrison and Wilhelm emphasize the difficulty in establishing and enforcing property rights over information. From this perspective, the investment bank is an institution for extra-legal enforcement of property rights over information. It accomplishes this task by serving as a repository for the reputation and relationships necessary to sustain relational contracts over information. But investment banks also produce information directly in the form of market research and advisory services. Traditionally, they engaged in relatively little direct trading on such information but rather packaged it either formally or informally with transaction services. In doing so, they altered the competitive dynamic between investors

²For example, see Luo (2005) for empirical evidence that firms weigh market reactions when deciding whether to carry through to completion an announced merger.

³Although it may not continue to be delivered primarily within large-scale, full-service investment banks. See Morrison and Wilhelm (2004, 2007b).

and entrepreneurs and therefore their incentives to produce and share information with one another. Our model focuses on this competitive tension in the market for information.

There is a relatively small body of related literature that examines how information production in financial markets is distributed across different types of information-producing agents. Admati and Pfleiderer [(1986), (1988b), (1990)] show that a monopolistic owner of information gains more from selling information indirectly by managing an asset fund than from direct sale to investors who then trade in financial markets on their own account. Fishman and Hagerty (1995) demonstrate that direct sale of information can arise among competing informed traders because direct sale commits them to trade more aggressively on their private information.⁴ Our model establishes conditions under which direct sale of information can arise even when it is difficult to contract for exclusive use of such information. Our analysis also is related to Morris's and Shin's (2002) study of how public information both conveys fundamental information to agents and coordinates their behavior. We extend their line of inquiry by endogenizing the structure of information production.

Our analysis also relates to a large vein of empirical research exemplified by Drucker and Puri (2005), Gande et al (1999), Asker and Ljungqvist (2006) and Ljungqvist et al (2006) that examines investment-banking relationships and how commercial bank entry and the growing prominence of institutional investors influence competition in the securities industry. The competitive effects from which welfare benefits arise in our model depend on the intermediary's inability to commit to narrow dissemination of sell-side information. As investors have grown larger and less diffuse credible informal commitments to narrow dissemination of sell-side information are more plausible. Moreover, our model suggests that sell-side information production, though potentially welfare enhancing, may require subsidization. But as traditional investment-banking relationships endure greater pressure from commercial banks, the mechanisms we identify for supporting sell-side research are strained. Thus our model suggests an avenue for exploring ongoing restructuring within the securities industry.

⁴Brennan and Chordia (1991) show that charging investors brokerage commissions is a way for investors to share risk with risk-neutral brokers. Vishny (1985) studies a brokerage firm's incentive to sell information in order to increase market liquidity when doing so increases potential trading commissions.

2 The Basic Model

We derive an analytical baseline in an economy with a liquid financial market. The model comprises four dates, three periods and one risky asset. The risky asset's payoff is realized at date 3 (the end of the third period) and is denoted $\delta + V$, where V is a known constant and δ is a random variable. The prior distribution of δ at date 0 is $N(0, \sigma_\delta^2)$. By convention, we define $v_\delta = \frac{1}{\sigma_\delta^2}$ as the random variable's precision and without loss of generality assume that $v_\delta = 1$. The discount rate across periods is normalized to be one.

2.1 Agents and Information

There are three types of risk-neutral agents in the economy: information-producing agents, market makers, and liquidity traders. There are N information-producing agents and for the sake of simplicity we assume that N is exogenously determined. Between date 1 and date 2, each information-producing agent receives one signal about the asset value. The signal of agent i , $i = 1, 2, \dots, N$, takes the form:

$$s_i = \delta + \varepsilon_i \tag{1}$$

where $\varepsilon_i \sim N(0, \sigma_i^2)$, δ and ε_i are independent for any i , and ε_i is independent across information-producing agents. The last assumption captures the feature that each agent has a unique perspective about the asset value.⁵ Notation is simplified by denoting $v_i \equiv \frac{1}{\sigma_i^2}$ and we further assume that all signals have the same quality so that $v_i = v_j = v$ for any i and j . Finally, without loss of generality, we assume that each agent's cost of receiving the signal is zero.

Market makers set the trading price in the financial market at date 2. Liquidity traders enter the financial market at date 2 with risky asset demand z that is normally distributed with mean zero and variance σ_z^2 .

⁵We consider a more general information structure later.

2.2 Sequence of Events

At date 0, each information-producing agent decides whether to trade on his private information (become a buy-side trader) or to sell his private information to one or more other information producers.⁶ After the information-producing agents specialize, there are m information sellers and $n \equiv N - m$ traders each of whom observes all other agents' decisions (m and n are determined endogenously). Information sellers cannot trade in the financial market. Buy-side traders cannot sell information directly, either their own (buy-side) information or any (sell-side) information bought from information sellers. They can only profit from their own information and any they acquire by trading in the financial market. This assumption effectively provides for the existence of a market for direct sale of information.

At date 1, before they receive signals about the asset value, information sellers make offers to traders in the market for information. Information seller j ($j = 1, 2, \dots, m$) makes take-it-or-leave-it offers for his sell-side information to a set of traders, F_j at prices $p(F_j)$. $p(F_j)$ is a vector whose elements are p_j^i , $i \in F_j$. p_j^i is the offer price that information seller j demands from trader i for the information.

Trader i ($i = 1, 2, \dots, n$) receives offers from a set of information sellers, S^i , at a vector of offering prices $p(S^i)$, whose elements are p_j^i , $j \in S^i$. Trader i does not observe any offers made to other traders, nor does he observe the (information) buying decisions of other traders.⁷ However, trader i does form beliefs about other offers conditional on the offers that he receives and conditions whether to accept an information seller's offer on these beliefs. If he accepts the offer from seller j , the trader pays p_j^i for the information. In exchange for this payment, seller j reports his signal to trader i . If trader i declines seller j 's offer, there is no payment and seller j does not report his signal to trader i . The set of sellers from whom trader i chooses to buy information is A^i , which is a subset of S^i . In the basic model, there are no sell-side agency problems. We discuss the consequences of agency problems in the conclusion.

After date 1, each information-producing agent receives a signal about the value of the asset and information sellers report their signals to the buy-side informed traders who have paid for them. At date 2, buy-side traders take positions in the financial market conditional on their information and their beliefs about other traders' information and strategies. The trading mechanism is similar to that in Kyle (1985).

⁶For technical completeness, we assume the presence of a coordination device that tells each information-producing agent which path to follow. In equilibrium, each agent finds it optimal to be guided by the coordination device.

⁷See Hart and Tirole (1990) and McAfee and Schwartz (1994) for more on multilateral contracting in a privately observable setting.

Traders do not observe current prices or quantities traded by other informed traders or by liquidity traders. Market makers do not receive any private information, nor do they observe individual quantities traded by the informed traders and the liquidity traders, but they do observe the total order flow, y , from all market participants. Each trader submits a market order, x_i and the market makers clear the market by supplying liquidity at a price, P_2 , conditioning on the total order flow y . We further assume that market makers do not observe the composition of information sellers in the economy. In other words, they do not know m , but they infer m correctly in equilibrium. Finally, at date 3, the security value is realized and distributed. The sequence of events is summarized in Figure 1.

The date 0 specialization decision is intended to represent the decision to deploy resources in investment banking (on the sell-side) or money management (on the buy-side). On the sell-side we envision direct sale of information encompassing not just analyst research but also, and perhaps more importantly, information and advice provided in securities underwriting and corporate transaction advisory functions. Large mutual funds and pension funds are obvious candidates for buy-side representatives in our model but we also envision private equity firms, hedge funds and other specialized concerns within this category.

Direct (non-soft-dollar) sale of sell-side analyst research to traditional money management operations is relatively uncommon. But such information also is less likely to be differentiated from information produced on the buy-side of the market and perhaps subject to more severe date 2 competition in the financial markets.⁸ By contrast, in securities offerings, especially IPOs, and corporate control or restructuring transactions, pronounced differences of opinion are more likely and barriers to trade among (usually, a smaller number of) financial market participants generally are more severe. Thus potential for differentiation between buy-side and sell-side research is greater and financial market liquidity, or the capacity for prices to respond to the arrival of new information, is diminished. It is in this context that we believe welfare effects associated with the decision to produce information from the sell-side are more likely of first-order consequence.

⁸We abstract from the fact that many modern investment banks have asset management divisions that effectively correspond with our buy-side traders. In general, sell-side and buy-side research efforts are separated by Chinese walls within the bank and the effective distance between the two has grown in recent years in response to criticism of poorly managed conflicts of interest.

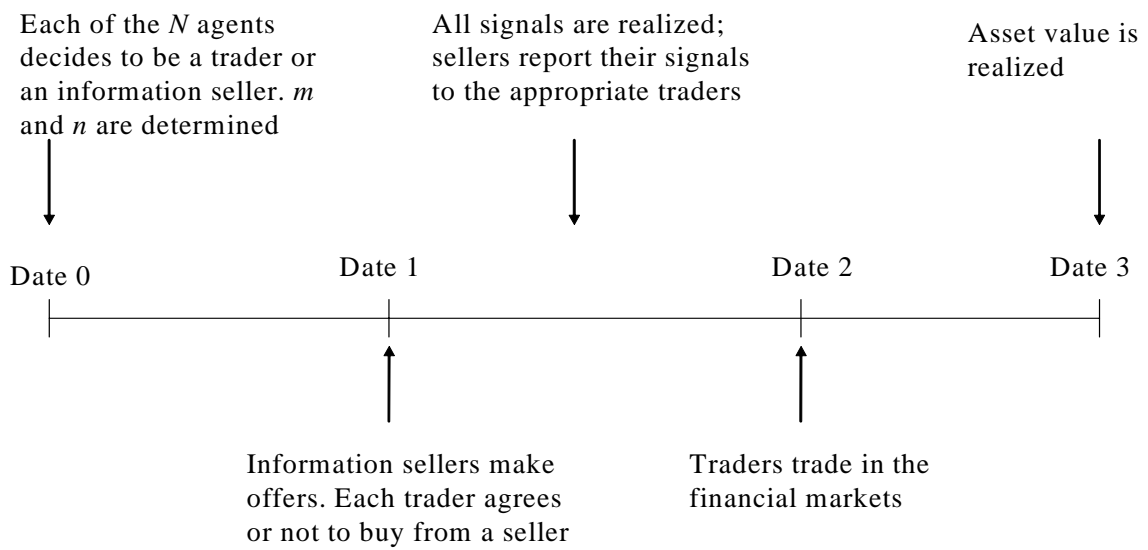


Figure 1: Sequence of Events

2.3 Definition of Equilibrium

The equilibrium concept used here is *Perfect Bayesian Equilibrium* (PBE). An equilibrium comprises the following components:

- (i) Each information-producing agent's choice of whether to specialize on the sell-side or the buy-side.
- (ii) The number of sellers, m^* .
- (iii) For seller j , the set of buy-side traders to whom information is offered, F_j , and the offer prices $p(F_j)$.
- (iv) For buy-side trader i , the set of sellers from whom information can be acquired, A^i .
- (v) The market order, x_i , submitted to market makers by trader i conditional on his information.
- (vi) The market makers' pricing conditional on total order flow, y .
- (vii) The information sellers' and traders' beliefs about offers made by other sellers and market makers' beliefs about the number of sellers and the traders' information structure.

In an equilibrium, conditional on other agents' equilibrium strategy, (a) each information seller (trader) finds it optimal to be a seller (trader); (b) based on his information and beliefs about other traders' information, trader i chooses the set of sellers, A^i , to buy information from to maximize his profit (trading profit minus the cost of buying information); (c) seller j chooses the set of traders, F_j , and prices $p(F_j)$ to maximize his total profit (investment-banking profit plus profit from selling information); (d) based on his information and beliefs about other traders' information, each trader submits an order to maximize his expected trading profit; (e) each market maker sets the trading price conditional on the total order flow to maximize his expected payoff; and (f) all beliefs are consistent with the equilibrium strategies of all the agents in the model.

3 A Benchmark Equilibrium

We focus on pure strategy equilibria in which trading strategies in the date 2 financial market are linear. The equilibrium is solved by backward induction beginning with the trading game comprising the informed traders' strategies and the market makers' pricing rule at date 2. Then we analyze date 1 trading in the market for information. Finally, we characterize the date 0 specialization decisions of the information-producing agents and the equilibrium number of information sellers.

The benchmark equilibrium analysis sheds light on two results that will be central to our arguments. First, we illustrate that buy-side and sell-side information have distinct effects on financial market prices. This is a result of externalities arising in competition among buy-side traders in the financial market. Second, we establish a baseline for further analysis of the information-producing agent's decision whether to specialize on the buy-side or the sell-side of the market for information.

To avoid obscuring these results, all proofs and much of the analytical machinery is relegated to the appendix. It is useful at this point to highlight one of the results proved in the appendix. At date 1, trading in the market for information is a multilateral contracting game with privately observable contracts. Under passive beliefs, the following lemma holds.⁹

Lemma 1 *Equilibrium with passive beliefs is characterized by each agent who specializes on the sell-side of the information market selling his information to every agent who specializes on the buy-side of the information market.*

Any information seller has incentive to deviate from an equilibrium in which he sells to a subset of buy-side traders because privately observable contracts prevent credible commitment to not doing so.¹⁰ This is a strong conclusion that imposes boundaries on the analysis. It is consistent with the relative difficulty of establishing and enforcing formal property rights over information and, as such, it enables us to examine conditions under which sell-side information production can occur absent any extra-legal enforcement arrangements. If, as Morrison and Wilhelm (2007) suggest, financial market intermediaries exist to enable relational contracts that rest on concerns for reputation, incentives for sell-side information production will be enhanced by both barriers to competition and the ability to commit to selling information to a subset of buy-side agents.

⁹If out-of-equilibrium beliefs are not restricted, there may be a plethora of PBE. See Bolton and Dewatripont (2005) for a summary of the literature. McAfee and Schwartz (1994) provide an extensive discussion of reasonable out-of-equilibrium beliefs for sharpening predictions about equilibrium outcomes, the most common of which is their *passive beliefs* restriction. We adopt this convention and note that it implies that upon receiving an out-of-equilibrium offer from a seller, trader i believes that all other offers remain equilibrium offers.

¹⁰See McAfee and Schwartz (1994) for analysis of supplier commitments to competing downstream firms under unobservability in a more general setting. We also assume a zero marginal cost in selling information. Given recent advances in information technology, this is not a particularly strong assumption.

3.1 Trading in the Financial Market

At date 2, liquidity traders, market makers, and n buy-side informed traders participate in the financial market. Lemma 1 implies that trader i 's information set is $F_i = \{s_i, s_1, \dots, s_m\}$; each informed trader has his own signal, s_i , and m signals purchased from information sellers. Conditional on this information, trader i ($i = 1, 2, \dots, n$) submits the market order x_i that maximizes his expected profit. Market makers observe only the total order flow, $y = \sum_{i=1}^n x_i + z$, and with information extracted from that observation, they establish the market clearing prices, $P_2(y)$. Thus, trader i 's problem is

$$\max_{x_i} E[x_i(V + \delta - P_2(\sum_{k=1}^n x_k + z)) | F_i]. \quad (2)$$

Each trader takes the pricing rule $P_2(\cdot)$ and other informed traders' strategies as given and exploits his information advantage by accounting for the impact of his trading decision on the date-2 price.

We do not model the market makers' strategic behavior directly. Rather, we assume that

$$P_2(y) = V + \eta y, \quad (3)$$

η is a positive number. We do this to show that our results do not depend on the specific market-clearing mechanism, but that the market-clearing price is linear in total order flow. This formulation includes the case in which the market makers are perfectly competitive:

$$P_2(y) = E[\delta | y] + V. \quad (4)$$

We propose that buy-side informed trader i 's trading strategy takes the symmetric form:

$$x_i = \beta s_i + a \left(\sum_{j=1}^m s_j \right), \quad (5)$$

¹¹It also includes the case where there is no market maker, but only uninformed risk-averse investors, as in Leland (1992).

where β and a measure how aggressively a buy-side agent trades on his own information and on sell-side information, respectively (this assumption is without loss of generality, since the unique linear equilibrium is symmetric as shown in Proposition 2). We can rewrite trader i ' strategy as

$$x_i = \beta s_i + \alpha s_p, \tag{6}$$

where $s_p = \frac{1}{m} \sum_{j=1}^m s_j$ and $\alpha = am$. Note that s_p is the sufficient statistic for δ , given all sell-side signals. We show in the appendix that this strategy is indeed the unique linear equilibrium and that it is characterized by Proposition 2:

Proposition 2 *There exists a unique linear equilibrium for date 2 trading, in which a buy-side agent's trading strategy is given by (5), where the market makers' pricing rule is given by (3) and trading intensities for sell-side and buy-side information are*

$$a = \frac{2v}{\eta(n+1)[2(1+mv) + (n+1)v]} \tag{7}$$

$$\beta = \frac{v}{\eta[2(1+mv) + (n+1)v]}. \tag{8}$$

Proposition 2 calls attention to the fact that (buy-side) informed traders exploit buy-side and sell-side information differently and thus these two sources of information have distinct effects on the market price. This is true in spite of the fact that buy-side and sell-side information are of the same quality. Corollary 3 outlines their effects on trading behavior and market prices:

Corollary 3 *(i) $\frac{na}{\beta} = \frac{2n}{n+1} \geq 1$ implies that buy-side traders, as a group, trade more aggressively on sell-side information than on their own information.*

(ii) $\frac{a}{\beta} = \frac{2}{n+1} \leq 1$ implies that individual buy-side traders trade less aggressively on sell-side information than on their own information.

(iii) Ceteris paribus, sell-side information generates more trading volume than does buy-side information.

(iv) Ceteris paribus, sell-side information has greater price impact than does buy-side information.

Buy-side traders *individually* trade less aggressively on sell-side information than on their own buy-side information because they recognize and fully internalize the private consequences of common knowledge of

the sell-side signal. Lemma 1 implies that any trader considering trading more aggressively on a one-unit increase in a sell-side signal recognizes that other traders are considering the same strategy. By contrast, the marginal price impact from trading more aggressively on a one-unit increase in one's own private signal is smaller because other buy-side traders are not expected to follow suit. Thus individual buy-side traders respond more aggressively to their own (buy-side) information than to sell-side information.

But common knowledge of the sell-side signal also creates greater scope for competition. By definition, a buy-side trader is a monopolist in his private buy-side signal. As a consequence, buy-side traders *collectively trade more aggressively on sell-side signals* because they do not fully internalize their individual impact on the market price. Given a one-unit increase in the sell-side signal, a one-unit increase in trading by a buy-side trader increases the price by η units. This reduces the individual trader's expected profit but he does not internalize the loss in trading profits imposed on the other $n - 1$ buy-side traders.

It is worth noting that $\frac{a}{\beta}$ is decreasing in n while $\frac{na}{\beta}$ is increasing in n . This means that the distinct price effects of buy-side and sell-side information are more pronounced when there are more buy-side traders in the economy. Finally, because the market makers' pricing rule is linear in total order flow, a greater change in order flow implies a greater change in price. Therefore, sell-side information is more influential in the sense that it generates a larger price impact.¹² Thus Proposition 2 and Corollary 3 identify a mechanism by which sell-side information production can promote financial market efficiency.

Note that any welfare benefits that might arise from increased price efficiency stem from the sell-side agent's inability to sell information to a subset of buy-side agents while excluding others. In other words, the inability to sustain arms-length, exclusive-use contracts over information is a double-edged sword. On the one hand, weak property rights undermine incentives to produce sell-side information. But if ample incentive is provided for producing such information, direct, non-exclusive sale promotes competition among agents whose trading activity leads to it being reflected in financial market prices. We now examine the conditions under which some agents will opt to produce information from the sell-side of the market.

¹²This is formally demonstrated in the appendix. Also see Chen (2004). With a fixed number of information-producing agents in the economy, increasing the number of sell-side agents, m , has offsetting effects on the revealed uncertainty in share prices. Corollary 3 shows that sell-side information is impounded in financial markets prices more aggressively than is buy-side information. On the other hand, increasing the number of sell-side agents reduces the number of, and therefore competition among, buy-side agents in the financial market. It can be shown, however, that when N goes to infinity while the total information in the economy $\Gamma = Nv$ is fixed, increasing the number of sell-side analysts unambiguously improves informational efficiency in the financial market. If all buy-side traders could commit to trading on sell-side information with the same intensity with which they trade on their own private information (that is, maintain a such that na equals the equilibrium β) they would earn greater trading profits, *ceteris paribus*.

4 Conditions that Support Sell-Side Information Production

4.1 Specialization in the Information Market

The final stage of the benchmark equilibrium analysis characterizes the specialization decision facing information-producing agents. In equilibrium m^* information-producing agents operate from the sell-side of the information market. The remaining information-producing agents buy information from the sell-side specialists and trade in the financial market conditional on both their own private information and that acquired from the sell-side.

The equilibrium definition implies that m^* is an equilibrium composition if and only if

$$\pi_b(m^*) \geq \pi_s(m^* + 1) \text{ if } m^* \leq N - 1, \text{ and} \quad (9)$$

$$\pi_s(m^*) \geq \pi_b(m^* - 1) \text{ if } m^* > 0. \quad (10)$$

The buy-side agent's incentive-compatibility condition, (9), implies a smaller profit if he unilaterally defects to the sell-side. Similarly, the sell-side incentive-compatibility condition, (10), prevents a sell-side agent unilaterally defecting to the buy side. Proposition 4 establishes that sell-side information production cannot be sustained in equilibrium under the conditions set out thus far.

Proposition 4 *In the absence of an external subsidy for sell-side information production, all information is produced from the buy-side of the information market in equilibrium.*

Proposition 4 is consistent with work by Holden and Subrahmanyam (1992) and others suggesting that trading profits available to a monopolist in private information should be no less than aggregate profits generated from the direct sale of private information. But taken together, Corollary 3 and proposition 4 suggest potential for welfare gains if there exists a means for sustaining sell-side information production. Obviously, a sufficiently large exogenous subsidy would satisfy the incentive-compatibility condition for sell-side information production. But this may not be necessary nor is it likely to be efficient. Instead, we explore next how unique sell-side information-production capacity might be used to exploit the competitive tension that gives rise in Corollary 3 to the tendency for buy-side agents, as a group, to trade more aggressively on sell-side information (with intensity α) than on their own information (with intensity β).

4.2 A Simple Example with Symmetric Information

Thus far we have assumed that there is no unique information production capacity on the sell-side of the market. Next we examine alternative information structures that could sustain sell-side production. We begin by assuming a unique (or complementary) sell-side information production technology. This is not an arbitrary assumption. Investment banks and other financial market intermediaries deal repeatedly with some counterparties and to a greater or lesser degree in their various intermediary capacities.¹³ It is not only plausible but, we believe, likely that such interaction yields insight that cannot be gained through buy-side information production. Moreover, quasi-rents stemming from reputational barriers to entry will mitigate forces that prevent sell-side agents from capturing a fair return on their investments in information.

We develop intuition with the special case of two information producing agents whose signals have correlated errors:

$$s_i = \delta + \epsilon_i, i = 1, 2, \tag{11}$$

with $Var(\epsilon_i) = \frac{1}{v}$ and $corr(\epsilon_1, \epsilon_2) = \rho$. Complementarity arises when the errors are negatively correlated so that combining the signals yields a more precise estimate of δ than either signal alone. In the extreme case where $\rho = -1$, obtaining both signals yields an estimate of δ with infinite precision in contrast to precision $1 + v$ for one signal.

If both agents produce information from the buy-side of the market each expects trading profit equal to

$$\pi_b(0) = \frac{1}{4\eta} \frac{4v(1+v)}{(2+3v+\rho)^2}. \tag{12}$$

Note that expected trading profits approach zero with the precision (v) of information signals.

By contrast, if one agent opts to produce information from the sell-side of the market, his expected profit from selling information is

$$\pi_s(1) = \frac{1}{4\eta} \frac{(1-\rho)v}{(1+v)(1+\rho+2v)}. \tag{13}$$

¹³See Morrison and Wilhelm (2007a, ch. 8) and Asker and Ljungqvist (2006).

If $\rho = -1$, the profit from selling information is positive ($\frac{1}{4\eta}$) even as signal precision goes to zero. The following proposition provides the condition under which one agent will opt to produce information from the sell-side of the market:

Proposition 5 *If $\rho \leq -v$, an equilibrium exists in which one agent will opt to produce information from the sell-side of the market without a subsidy.*

Two forces drive this result. First, in the special case where there are only two agents, their total trading profit is maximized when one trades monopolistically with their private information. Second, the sell-side information producer maintains considerable bargaining power because failure to acquire sell-side information sharply diminishes expected trading profits. Buy-side traders are thus relatively insensitive to the price set for sell-side information. This enables the sell-side producer to capture a large fraction of the expected trading profits. In other words, although the sell-side producer sacrifices monopoly power over the information he produces, this sacrifice is more than compensated by rents captured by, but extracted from, the buy-side trader. This result generalizes to cases where there are more than two agents. Although sell-side agents lose monopoly power over the information they produce, sufficient bargaining power over buy-side producers yields a net expected private benefit to sell-side information production.¹⁴ Client relationships and the reputations on which they rest provide a natural barrier to entry and access to unique information that reinforce such bargaining power.

4.3 Asymmetric Information Production with Large N

Because it can be shown that the lower bound on ρ in the information structure assumed in the preceding section ($corr(\epsilon_i, \epsilon_j) = \rho$, for any $i \neq j$) is $-\frac{1}{N-1}$, the simple symmetric information structure sustains unsubsidized sell-side information production only when the number of information-producing agents is small. In this section we explore the limits of unsubsidized sell-side production when agents produce information asymmetrically. We do so by imposing the following information structure on agent signals:

$$s_i = \delta + \epsilon_i + \gamma_i. \tag{14}$$

¹⁴We thank the editor and the referee for drawing attention to this result.

The noise terms, ϵ_i and γ_i have precision v and v_γ , respectively, and γ_i and γ_j are independent for any $i \neq j$. To keep things simple, we assume that agent 1 has unique, complementary information-production capacity in the sense that $\epsilon_1 = -\epsilon_i$, for any $i \neq 1$. The following proposition shows that with sufficiently strong complementarity, there is *no* equilibrium in which all agents produce information from the buy-side of the market. Further, we establish a condition under which only agent 1 produces information from the sell-side of the market.

Proposition 6 (i) *When v is low, there is no equilibrium in linear strategies with passive beliefs in which all agents produce information from the buy-side of the market.*

(ii) *When v is low and v_γ is sufficiently high, there is an equilibrium in which only agent 1 produces information from the sell-side of the market.*

The first condition arises because the marginal value of agent 1's complementary signal is high when signals have low precision. In this case, if all agents opt to produce information from the buy-side, monopolistic trading on low precision signals yields modest trading profits. If agent 1 opts to produce information from the sell-side, his complementary signal, when joined with others' signals yields substantially larger trading profits in spite of the fact that buy-side agents trade aggressively on the more precise information now at their disposal. Agent 1 has incentive to produce from the sell-side if he can command a sufficiently large share of buy-side trading profits.

The incentive to produce information from the sell-side extends beyond a single agent when v is low. Because agent 1 commands a large fraction of the trading profits, other buy-side agents have little to lose from opting to produce sell-side information. Moreover, once buy-side agent i acquires agent 1's signal, ϵ_i is eliminated. The remaining noise in agent i 's information arises from γ_i and γ_1 . If another agent, 2, also opts for sell-side production then his information sold to the remaining buy-side agents further increases the precision of information on which they trade in the financial market. Fewer buy-side agents trading on more precise information yields additional profits in which agent 2 can then share. Because these profits stem from reducing noise associated with γ_i and γ_1 , they persist as v goes to zero. Thus agent 2 has incentive to produce sell-side information if v_γ is not too high. This implies that multiple agents may opt for the sell-side of the market in equilibrium (if one exists).¹⁵

¹⁵Exploring equilibria with multiple sell-side agents is complicated by increasing returns to scale potentially arising with complementarity among signals. As a consequence, prices for sell-side information may be indeterminate. The proof of

5 The Welfare Effects of Sell-Side Information Production

Thus far we have ignored any real effects associated with information production. As a consequence, the sustainability of sell-side information production has depended entirely on the sell-side agent's capacity for extracting trading rents from buy-side traders. Buy-side traders profit from their own and sell-side private information at the expense of liquidity traders. In other words, there are no efficiency gains sustaining sell-side information production but rather an exogenous wealth transfer mechanism running from liquidity traders to sell-side information producers through privately-informed, buy-side traders.

An alternative transfer mechanism for sustaining the positive externality generated by sell-side information production arises if more informative financial market prices lead to better real investment decisions. Our model lends itself to a straightforward application of Leland's (1992) model of the welfare effects of information production in the presence of a financial market.¹⁶ Real investment decisions, and thus firm profits, benefit from an informationally efficient financial market. Informational efficiency is a function of the type of information produced (buy-side or sell-side) because type determines the intensity with which it is impounded in financial market prices through the trading behavior of buy-side agents. Assuming that firms condition real investment decisions on date-2 share prices determined in the financial market, it is easy to show that welfare increases with the informational efficiency of date-2 share prices.¹⁷

Corollary 3 demonstrates that sell-side information is impounded more aggressively into financial market prices than is buy-side information. Other things equal, sell-side information production promotes welfare by increasing the precision of signals guiding real investment decisions. We refer to this welfare effect as the *sell-side effect*. But if there is a fixed number of information-producing agents in the economy, an offsetting *competition effect* arises – as more agents opt for sell-side production, competition *among* buy-side traders is diminished. Thus date-2 financial market prices provide less precise signals. The relative magnitudes of the sell-side and competition effects determine whether increasing sell-side information production improves or diminishes welfare.¹⁸ As the number of information-producing agents, N , increases, ambiguity in the

proposition 6 illustrates that even in the simple case where there are only two sell-side agents, there are a continuum of equilibrium prices for their information.

¹⁶See Chen (2004) for details.

¹⁷See Baker, Stein, and Wurgler (2003) for a review of the literature on the relation between asset prices and corporate investment. Note that because all agents in our model are assumed to be risk neutral, the well-known Hirshleifer (1971) Effect does not apply.

¹⁸See Chen (2004) for the sufficient condition under which increasing the number of sell-side agents improves informational efficiency.

welfare analysis diminishes. When N goes to infinity while the total information in the economy, Nv , is fixed, increasing the number of sell-side agents unambiguously promotes welfare.

In summary, the analysis in section 4 identifies information structures under which profits arising from exploitation of liquidity traders are perhaps a feasible source of compensation for the externality generated by sell-side information producers. However, such an arrangement is limited by the capacity for liquidity traders to absorb the cost. This seems a tenuous, if plausible, arrangement. On the other hand, if real investment decisions improve and profits increase with the production of sell-side information, the firms that are the subject of information production are a more natural and perhaps richer source of compensation.

Before examining how sell-side information producers might capture a share of the welfare benefits they produce, it is fair to ask whether such welfare effects are nontrivial and, if so, under what conditions. As Leland (1992) notes, welfare should increase when the amount of investment is highly responsive to the firm's stock price. From this perspective we believe that any welfare benefits arising from the sort of information produced by most Wall Street research analysts are likely to be small. With the possible exception of their having somewhat greater access to senior managers of the firms they cover, it is not obvious that they have unique production capacity relative to their peers on the buy-side of the market.¹⁹ Moreover, to the extent that the information they produce is incremental to investor evaluations of the firm rather than transformational, one would expect a liquid financial market to diminish the marginal benefits from having such information produced from the sell-side of the market. Trading on such information would not strain market liquidity and therefore it should be reflected rapidly in market prices.

If this is true, sell-side research will be difficult to sustain regardless of the sell-side agent's capacity for capturing any externalities generated by their presence – their marginal contribution to market efficiency is simply too modest. In such circumstances, it is perhaps not surprising that sell-side research flourishes only when it is subsidized by or bundled with other products or services. This perspective might also shed light on why sell-side analyst research apparently was more readily sustained in the past. Relatively primitive communications technology would tend to amplify any unique production capacity on the sell-side of the market. But as technological advances have enabled virtually costless (at the margin) and instantaneous dissemination of information, direct, exclusive sale of such information becomes more difficult.

¹⁹See Lim (2001) and Chen and Matsumoto (2006) for evidence that analysts gain or sustain access via favorable forecasts.

Suppose instead that new information bears heavily on outsiders' evaluations of the firm. Suppose also that capacity for producing and trading on such information is concentrated narrowly on the buy-side of the market. These assumptions roughly characterize conditions around corporate control and restructuring events where relatively few investors command sufficient capital to bid credibly for control. In this setting, buy-side traders will likely derive greater monopoly power from their private information as limited participation heightens potential for (tacit) collusion. In a more general auction setting Bulow and Klemperer (1996) argue that *no amount of bargaining power is as valuable to a seller as attracting one extra bona fide bidder*.

But bona fide bidders are few in such extraordinary circumstances. As a consequence, a target firm has ample incentive to increase its bargaining power with the bidders at hand. Our model suggests a mechanism for doing so. By entering a relationship with an investment bank a firm enables that bank to develop a unique information-production capacity with respect to the firm. When the firm's production technology or conditions in its product market are fundamentally altered such that future investment decisions are quite sensitive to new information, having established a credible sell-side information producer can have a substantial marginal effect on the competitive behavior of buy-side agents seeking to exploit their own private information relative to the state of the firm. Alternatively, one might think of the firm as creating an additional bona fide bidder by virtue of having granted access that provides the bank with unique information-production capacity.

Maintaining a close relationship surely depends on a bank not directly exploiting unique access to information about the firm. To that end, it is not unusual for investment banks to publicly commit to representing one side or the other in the market for corporate control or to establish advisory functions at arms length from proprietary trading functions.²⁰ Just as the bank is handcuffed by the relationship, so is the firm as it forfeits bargaining power with a relationship bank. But this may be necessary for the bank to internalize a sufficient share of the surplus arising from its presence on the sell-side of the market (requiring a commitment to not trade directly on its private information). When the sell-side agent's marginal effect is large it must extract more of the surplus generated by its sell-side presence from the firm as the firm captures the benefits of more aggressive bidding among buy-side traders. Under such circumstances the

²⁰For example, Goldman Sachs long maintained a policy of not representing parties attempting hostile takeovers. Similarly, boutique advisory firms such as Greenhill emphasize their capacity for providing advice that is uncolored by conflicts of interest that might arise in full service firms that also maintain substantial proprietary trading operations.

large fees associated with corporate control transactions are perhaps not surprising. Firms have incentive to pay high fees because doing so effectively subsidizes sell-side information production which, in turn, improves investment decisions by promoting financial market efficiency.

Finally, it is worth considering the fragility of an equilibrium in which sell-side information production substantially improves welfare. The mechanism that generates sell-side benefits rests in large part on the sell-side agent's inability to commit to (or contract for) exclusive dissemination of its information. As we noted earlier, Morrison and Wilhelm (2007) contend that the primary economic function of investment banks has been to provide extralegal enforcement of relational contracts where formal contracts are weak. If investment banks maintain close relationships with institutional investors as well as with operating firms, the mechanism we've described would be weakened by their ability to informally (but credibly) commit to narrow direct sale of sell-side information.

Historically, at least two forces mitigated this threat. First, the rise of institutional investors is a relatively recent event in capital market history. Our assumption that sell-side producers cannot commit to narrow direct sale of their information is more plausible when investors are numerous and diffuse. Second, a bank's concern for its relationships with client firms serves as a counterbalance to its incentive to excessively favor one or a few institutional investors. In their intermediary capacity, investment banks succeed by developing reputations for successfully balancing the conflicting interests of their clients, on the one hand, and investors, on the other. The rising influence of institutional investors and challenges to traditional relationships posed by commercial banks undermine these mitigating forces.²¹ Thus our model suggests an avenue for exploring why investment banks have struggled recently to maintain margins in their advisory functions and to carry out such functions alongside large-scale trading operations.²²

6 Conclusion

The model presented in this paper builds on Kyle (1985) and Leland (1992) to provide a framework for studying the choice between producing information for private trading in a financial market or for sale to those who would then trade on both purchased information and their own private information.

We characterize agents who opt to produce information strictly for sale as intermediaries and identify

²¹See Drucker and Puri (2005), Gande et al (1999) and Ljungqvist et al (2006) for evidence on commercial bank entry to investment-banking functions.

²²See Morrison and Wilhelm (2007, Ch. 10) for further elaboration of the forces at play in this market segment.

investment banking functions as the sort of intermediation that the model is intended to explain. We show that sell-side information production has unique bearing on competition among (privately informed) traders in the financial market and thus its presence can improve price efficiency. If real decisions benefit from more informationally efficient financial market prices, the presence of sell-side information producers also increases welfare. The competitive benefits arising from sell-side production stem from the inability of sell-side agents to credibly commit to exclusive or even narrow dissemination of the information they sell.

In spite of its benefits, sell-side information production is difficult to sustain for much the same reason. Because contracting over information is difficult, sell-side producers have limited capacity for sharing in the positive externality generated by their presence. We demonstrate conditions under which sell-side information production can be sustained (without an external subsidy) and when it cannot. We argue that sell-side information of the sort associated with research analyst reports will be difficult to sustain in the absence of a subsidy but also less worthy of concern were it not. By contrast, we argue that sell-side information produced in the context of corporate advisory functions (i.e., mergers and acquisitions or restructuring transactions) is more likely to have significant welfare effects and also more readily sustained under current industry conditions. The latter argument rests on the ability of operating firms to credibly commit to sharing welfare benefits with (or pay high fees to) their advisors within the context of repeated bank-client relationships.

Our interpretation of the analysis suggests that the model is useful for thinking about ongoing restructuring within the investment-banking industry but it also draws attention to a potentially useful extension of the model. The economic tension that gives rise to our results derives from our assumption that sell-side agents are limited in their ability to contract over information. However, as institutional investors have gained prominence in financial markets, it is easy to imagine improved relational contracting between investment banks and buy-side (institutional) traders (investors). At the same time, the relational contracts between operating firms and investment banks that yield fees capable of sustaining sell-side information production are almost certainly weaker by virtue of competition from commercial banks. A formal analysis of these important recent changes in the industry requires modeling the investment bank (or sell-side agent) from a double-sided agency perspective. This extension would enable explicit analysis of the investment bank's role in balancing the competing interests in information among the investors and operating firms between which their fundamental economic functions are carried out.

Appendix

Proof of Lemma 1: Suppose instead that there existed an equilibrium in which sell-side agent j did not sell to buy-side agent i . Because having agent j 's information can never reduce agent i 's profit, this alternative implies that agent i values agent j 's information at zero. Otherwise agent j would gain by making an offer to i at a positive price and i would accept the offer. This contradicts the equilibrium definition.

Under passive beliefs, if i values j 's information at zero, i 's trading strategy x_i must be the same with s_j as without s_j given the uniqueness of the buy-side agent's problem $\max_{x_i} E[x_i(V + \delta - (V + \eta y))|F_i]$, where F_i is i 's equilibrium information set. The first-order conditions for x_i thus imply that

$$\begin{aligned} x_i(F_i) &= \frac{E[\delta|F_i] - \eta \sum_{k \neq i} E[x_k|F_i]}{2\eta} \\ &= \frac{E[\delta|F_i, s_j] - \eta \sum_{k \neq i} E[x_k|F_i, s_j]}{2\eta} \\ &= x_i(F_i, s_j) \end{aligned}$$

for any realization of signals in F_i and s_j . $E[\delta|F_i]$ and $E[\delta|F_i, s_j]$ are linear in agent i 's signals. The linear equilibrium implies that $E[x_k|F_i]$, and $E[x_k|F_i, s_j]$ are also linear in i 's signals. Matching coefficients yields a set of linear equations on the model parameter values. For model parameter values outside the set defined by these equations, $x_i(F_i) \neq x_i(F_i, s_j)$, which is a contradiction. The set of parameter values defined by the set of equations is of measure zero in the Euclidean space. Therefore, Lemma 1 holds generically.

Proof of Proposition 2: Substituting equations (3) and (6) into buy-side agent i 's objective function (2) and simplifying yields:

$$\max_{x_i} x_i \{ E[\delta|F_i] - \alpha\eta(n-1)s_p - \beta\eta(n-1)E[\delta|F_i] - \eta x_i \}, \quad (15)$$

where $E[\delta|F_i] = \frac{mvs_p + vs_i}{1+mv+v}$ by Bayes rules. The first-order condition for this problem is

$$\begin{aligned} x_i^* &= \frac{[1 - \beta\eta(n-1)]E[\delta|F_i] - \alpha\eta(n-1)s_p}{2\eta} \\ &= \frac{1}{2\eta} \left\{ [1 - \beta\eta(n-1)] \frac{mv}{1+mv+v} - \alpha\eta(n-1) \right\} s_p + [1 - \beta\eta(n-1)] \frac{v}{1+mv+v} s_i. \end{aligned} \quad (16)$$

Because $x_i = \alpha s_p + \beta s_i$ in symmetric equilibrium:

$$\alpha = \frac{1}{2\eta} \left[(1 - \beta\eta(n-1)) \frac{mv}{1+mv+v} - \alpha\eta(n-1) \right], \quad (17)$$

$$\beta = \frac{1}{2\eta} (1 - \beta\eta(n-1)) \frac{v}{1+mv+v}. \quad (18)$$

Solving equations (17) and (18) yields α and β .

A general linear trading strategy is defined as $x_i = \beta_i s_i + \sum_{j \in A^i} \alpha_i^j s_j$. Equations (17) and (18) thus become

$$2\eta\beta_i = \frac{v}{1+mv+v} (1 - \eta \sum_{j \neq i} \beta_j), \quad (19)$$

$$2\eta\alpha_i^l = \frac{v}{1+mv+v} (1 - \eta \sum_{j \neq i} \beta_j) - \eta \sum_{j \neq i} \alpha_j^l, \quad \forall l \text{ such that } s_l \in A^i. \quad (20)$$

Subtracting $\frac{v}{1+mv+v} \eta \beta_i$ from both sides of equation (19) and rearranging terms yields

$$\beta_i = \frac{1}{(2 - \frac{v}{1+mv+v})\eta} \frac{v}{1+mv+v} (1 - \eta \sum_j \beta_j).$$

Therefore, $\beta_i = \beta_j = \beta$, for any i and j . Similarly, subtracting $\eta\alpha_i^l$ from both sides of equation (20) and rearranging terms yields $\alpha_i^l = \frac{1}{\eta} [\frac{v}{1+mv+v} (1 - \eta(n-1)\beta) - \eta \sum_j \alpha_j^l]$, or $\alpha_i^l = \alpha_j^l = a_l$ for any i and j . Substituting a_l and β into equation (20), yields $a_l = \frac{1}{(n+1)\eta} \frac{v}{1+mv+v} (1 - \eta(n-1)\beta)$. That is, $a_l = a_q = a$ for any l and q . Thus the symmetry assumption is without loss of generality. Since α , β are uniquely determined, the uniqueness of the linear equilibrium follows.

Proof of Corollary 3: Proofs of Part (i), (ii), and (iii) follow directly. For part (iv), the volume generated by sell-side agent j and by buy-side agent i are $naE[|s_j|]$ and $\beta E[|s_i|]$, respectively. Because $\beta > na$, as shown in part (i), and s_i and s_j are identically distributed, $naE[|s_j|] > \beta E[|s_i|]$.

Proof of Proposition 4: To save space, we only give an outline of the proof here. For a detailed proof, see Chen (2004). We start our analysis by characterizing the market for information at date 1.

We first look at a buy-side agent's demand for the sell-side agents' information. More specifically, given the set, S^i , of sell-side agents who offer signals for sale, how should buy-side agent i determine the subset, A^i , of sell-side agents from whom to buy signals? After choosing any A^i , agent i maximizes his expected trading profit given his own signal and signals he bought, with the belief that everybody else will play the equilibrium strategy: every other trader buys from all of the sell-side agents and trade according to the strategy specified in Proposition 2. . Chen (2004) shows that agent i ' trading profit depends only on the number of sell-side agents from whom he buys information, i.e., $\pi_i(A^i) \equiv \pi_i(l)$, where $l \equiv l(A^i)$, the number of sell-side agents in A^i . Furthermore, $\pi_i(l)$ is strictly increasing and concave in l . As a result, when agent i is faced with sell-side offers, $p(S^i)$, he will choose to buy from the cheapest l^* sellers. l^* is largest number of sell-side agents in S^i such that that the marginal benefit of the sell-side agent's information is greater than the price he charges.

We then study the prices that sell-side agents offer for their information. Because they makes take-it-or-leave-it offers to buy-side agents, they extract the entire marginal surplus of their information. By Lemma 1, the equilibrium number that a buy-side agent buys information from is m . We thus can verify that a sell-side agent's offering price is $p_j^i = p = \pi(m) - \pi(m - 1)$ in equilibrium (symmetry enables dropping the subscript i).

In sum, in equilibrium, all buy-side agents buy information from all sell-side agents at price p . The buy-side agent's profit is thus $\pi_b(m^*) \equiv \pi(m^*) - m^*p$; and the sell-side agent's profit is $\pi_s(m^*) \equiv np$.

Finally, we prove Proposition 4 by showing that (10) is impossible to satisfy for any $m^* > 0$. That is, $\pi_s(m^*) < \pi_b(m^* - 1)$ for all $m^* \geq 1$. The proof of this equation involves quite some algebra, and is detailed in Chen (2004).

Proof of Proposition 5: Suppose, without loss of generality, in equilibrium agent 1 opts for the sell-side of the market and agent 2 remains on the buy-side. If agent 1 deviates so that both agent 1 and 2 produce information from the buy-side of the market, agent i 's trading strategy is

$$\max_{x_i} E[x_i(V + \delta - (V + \eta y)) | F_i],$$

The optimal solution is $x_i = \frac{E[\delta|F_i] - \eta E[x_j]}{2\eta}$. Assuming $x_i = \beta_i s_i$ for $i = 1$ and 2, we get

$$\begin{aligned} x_i &= \frac{1}{2\eta} \{E[\delta|s_i] - \eta\beta_j E[s_j|s_i]\} \\ &= \frac{1}{2\eta} [v - \eta\beta_j(v + \rho)] \frac{1}{1+v} s_i. \end{aligned}$$

The second equation follows because $E[\delta|s_i] = \frac{vs_i}{1+v}$ and $E[s_j|s_i] = \frac{v+\rho}{1+v}$. The conditional expectation of joint normal distribution is given by the following well-known result from Anderson (2003).

Theorem 7 If $\begin{pmatrix} X_1 \\ X_2 \end{pmatrix} \sim N(\mu, \Sigma)$, where $\mu = \begin{pmatrix} \mu_1 \\ \mu_2 \end{pmatrix}$ and $\Sigma = \begin{pmatrix} \Sigma_{11} & \Sigma_{12} \\ \Sigma_{21} & \Sigma_{22} \end{pmatrix}$, then $X_1|X_2 = a \sim N(\bar{\mu}, \bar{\Sigma})$, where $\bar{\mu} = \mu_1 + \Sigma_{12}\Sigma_{22}^{-1}(a - \mu_2)$, and $\bar{\Sigma} = \Sigma_{11} - \Sigma_{12}\Sigma_{22}^{-1}\Sigma_{21}$.

We thus have two equations, $\beta_i = \frac{1}{2\eta} [v - \eta\beta_j(v + \rho)] \frac{1}{1+v}$, for $i = 1$ and 2. Solving them, we get $\beta_i = \beta_j = \frac{v}{\eta(2+3v+\rho)}$. Each agent's trading profit is

$$\begin{aligned} \pi_b(0) &= \frac{1}{4\eta} E\left\{ [v - \eta\beta_j(v + \rho)] \frac{1}{1+v} s_i \right\}^2 \\ &= \frac{1}{4\eta} \left\{ [v - \eta\beta_j(v + \rho)] \frac{1}{1+v} \right\}^2 \left(1 + \frac{1}{v}\right) \\ &= \frac{1}{4\eta} \frac{4v(1+v)}{(2+3v+\rho)^2}. \end{aligned}$$

If agent 1 does not deviate, he sells his information to agent 2, who is the trader. The first-order condition for the buy-side agent's trading strategy is

$$\begin{aligned} x_2 &= \frac{1}{2\eta} E[\delta|F_2] \\ &= \frac{1}{2\eta} \frac{(s_1 + s_2)v}{1+2v+\rho}. \end{aligned}$$

His trading profit is $\pi(1) = \frac{1}{4\eta} \left(\frac{v}{1+2v+\rho}\right)^2 \text{Var}[s_1 + s_2] = \frac{1}{4\eta} \frac{2v}{1+2v+\rho}$. However, if he does not buy information from agent 1, his trading strategy is $x_2 = \frac{1}{2\eta} E[\delta|s_2] = \frac{1}{2\eta} \frac{v}{1+v} s_2$. His trading profit is $\pi_b(1) = \frac{1}{4\eta} \frac{v}{1+v}$. Since

the sell-side agent makes a take-it-or-leave-it offer, the price for his information, which is also his profit, is thus

$$\begin{aligned}\pi_s(1) &= p = \pi(1) - \pi_b(1) \\ &= \frac{1}{4\eta} \frac{(1-\rho)v}{(1+v)(1+\rho+2v)}.\end{aligned}$$

Therefore, agent 1 would not have incentive to deviate if $\pi_s(1) \geq \pi_b(0)$, which is equivalent to

$$\frac{(1-\rho)v}{(1+v)(1+\rho+2v)} \geq \frac{4v(1+v)}{(2+3v+\rho)^2}.$$

That is,

$$(2+3v+\rho)^2(1-\rho) - 4(1+v)^2(1+\rho+2v) \geq 0. \quad (21)$$

The right-hand-side is a 3rd order polynomial of ρ , with only one real root, $-v$. Since the right-hand-side derivative with respect to ρ is negative at $\rho = -v$, we can conclude that if $\rho \leq -v$, (21) is true, and agent 1 has no incentive to deviate. As for (buy-side) agent 2, if he deviates while agent 1 does not, both agents become earn zero profit from the sell-side of the market. So agent 2 will not deviate.

Proof of Proposition 6: The equations in this proof are derived using Mathematica. The program is available upon request. For part i), suppose there is an equilibrium in which all $N = n + 1$ agents choose to be traders. Suppose the agents' trading strategies are linear, i.e., $x_i = \beta_i s_i$. For agent i , the first-order condition of his strategy is

$$x_i = \frac{1}{2\eta} \{E[\delta|s_i] - \eta \sum_{j \neq i} \beta_j E[s_j|s_i]\} \quad (22)$$

We know from theorem 7, $E[\delta|s_i] = \frac{1}{1+\sigma+\phi} s_i$, and $E[s_j|s_i] = \frac{1-\sigma}{1+\sigma+\phi} s_1$ if either i or j is 1. Here for the ease of notation, $\sigma = \frac{1}{v}$, and $\phi = \frac{1}{v_\gamma}$. Further, $E[s_j|s_i] = \frac{1+\sigma}{1+\sigma+\phi} s_i$, for $i, j \neq 1$. Therefore, for agent 1,

$$\beta_1 = \frac{1}{2\eta} \left(\frac{1}{1+\sigma+\phi} - \eta \sum_{j \neq 1} \beta_j \frac{1-\sigma}{1+\sigma+\phi} \right) \quad (23)$$

For agent $i \neq 1$,

$$\beta_i = \frac{1}{2\eta} \left(\frac{1}{1 + \sigma + \phi} - \eta \sum_{j \neq 1, i} \beta_j \frac{1 + \sigma}{1 + \sigma + \phi} \right) - \eta \beta_1 \frac{1 - \sigma}{1 + \sigma + \phi} \quad (24)$$

From this equation, we can conclude that $\beta_i = \beta_j = \beta$ for any $i \neq 1$ and $j \neq 1$ using the method as in the proof of Proposition 2. We then solve for the unique β and β_1 using equations (23) and (24). Because the solution is too complicated, we do not report it here. The trading profit for agent 1 is thus

$$\begin{aligned} \pi_b^1(0) &= \eta E[x_1^2] \\ &= \eta \beta_1^2 (1 + \sigma + \phi) \\ &= \frac{vv_\gamma(v + v_\gamma + vv_\gamma)(v_\gamma + 2nv_\gamma + v(2 + v_\gamma))^2}{[(2 + n)v_\gamma^2 + 2vv_\gamma(3 + n + 2v_\gamma + 3nv_\gamma) + v^2(2 + v_\gamma)(2 + (2 + n)v_\gamma)]^2 \eta}. \end{aligned}$$

The first equation follows from by using (22) to calculate agent 1's trading profit. The second equation follows because $E[s_1^2] = 1 + \sigma + \phi$. The third equality follows by substituting in β_1 .

Now suppose agent 1 deviates to the sell-side. By the same logic as in Lemma 1, each of the n buy-side agents would buy from the the sell-side agent in equilibrium. By the same steps as solving for the benchmark equilibrium, that is, 1) we first solve for all buy-side agents' unique linear strategy, which is symmetric; 2) then calculate a buy-side agent's total trading profit, $\pi(1)$; 3) then calculate his profit if he does not buy sell-side information, $\pi_b(1)$; finally 4) the price for sell-side information is thus $p = \pi(1) - \pi_b(1)$, and the sell-side agent's profit is $\pi_s^1(1) = np$, we can solve for the unquie equilibrium profit for sell-side agent 1,

$$\pi_s^1(1) = \frac{4nv_\gamma(1 + 2v_\gamma)(v + 2v_\gamma)(v + v_\gamma + nv_\gamma)^2}{(1 + n)v_\gamma^2(v + v_\gamma + vv_\gamma)[2v + (3 + n)(1 + v)v_\gamma + 4(1 + n)v_\gamma^2]^2 \eta}$$

Agent 1 has incentive to deviate to the sell-side of the market if and only if

$$\pi_s^1(1) - \pi_b^1(0) > 0. \quad (25)$$

But

$$\lim_{v \rightarrow 0} \pi_s^1(1) - \pi_b^1(0) = \frac{8v_\gamma(n + 2nv_\gamma)}{(3 + n + 4(1 + n)v_\gamma)^2 \eta} > 0,$$

therefore, as v approaches 0, all agents opting for the buy-side of the market cannot be an equilibrium in which they all follow linear trading strategies and the out-of-equilibrium belief is passive. We thus have proved part (i).

As for part (ii), we first check that if all agents but agent 1 become buy-side agents, none will deviate to the sell-side. Suppose without loss of generality that agent 2 deviates to the sell-side. That is in equilibrium there are $n - 1$ buy-side agents and 2 sell-side agents (1 and 2). We will show that agent 2's profit from selling information, $\pi_s^2(2)$ is no more than his equilibrium trading profit $\pi_b(1)$. By the same logic as in Lemma 1, in equilibrium all buy-side agents buy information from all sell-side agents. We first calculate each buy-side agent's equilibrium strategy and trading profit, $\pi(2)$. Second we calculate agent 2's profit from selling information $\pi_s^2(2)$. Notice that now, agent 1 and 2 have complementary signals, in that the sum of the marginal contributions of their signals to a buy-side agent's profit may be larger than their individual marginal contributions.²³ As a result, the prices for their information may not be uniquely determined.²⁴ However, we know that the price for an agent's information should be no more than its marginal contribution to a buy-side agent's trading profit. Otherwise he would not buy the information. That is, the price for agent 2's information satisfies

$$p_2 \leq \pi(2) - \pi(\text{analyst 1})$$

where $\pi(\text{agent 1})$ is a buy-side agent's trading profit from buying from agent 1 only. Therefore, $\pi_s^2(2) \leq (n - 1)[\pi(2) - \pi(\text{agent 1})]$. Some tedious algebra yields that

$$\lim_{v_\gamma \rightarrow \infty} \pi_b(1) - \pi_s^2(2) \geq \lim_{v_\gamma \rightarrow \infty} [\pi_b(1) - (n - 1)[\pi(2) - \pi(\text{agent 1})]] = \frac{v}{(1 + n)^2(1 + v)\eta} > 0. \quad (26)$$

That is, agent 2 would not have incentive to deviate to be a sell-side agent if v_γ is large. On the other hand, if (25) holds, agent 1 would not deviate as shown in the proof of part (i). Some algebra yields that

$$\lim_{v \rightarrow 0} \lim_{v_\gamma \rightarrow \infty} \pi_s^1(1) - \pi_b^1(0) = \frac{n}{(1 + n)^2\eta} > 0. \quad (27)$$

²³That is, $\pi(2) - \pi(\text{analyst 1}) + \pi(2) - \pi(\text{analyst 2}) > \pi(2) - \pi(0)$.

²⁴More specifically, the prices for both signals can be any pair such that $p_1 + p_2 = \pi(2) - \pi(0)$, $p_1 \leq \pi(2) - \pi(\text{agent 2})$, and $p_2 \leq \pi(2) - \pi(\text{agent 1})$.

(26) and (27) imply that there exists a $\bar{v} > 0$ such that for any $0 < v < \bar{v}$, if $v_\gamma > \bar{v}_\gamma(v)$, where $\bar{v}_\gamma(v)$ may depend on v , both $\pi_b(1) - \pi_s^2(2) > 0$ and $\pi_s^1(1) - \pi_b^1(0) > 0$. In other words, if v is small and v_γ is large, neither agent 1 nor agent 2 has incentive to deviate. We thus have proved part (ii).

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